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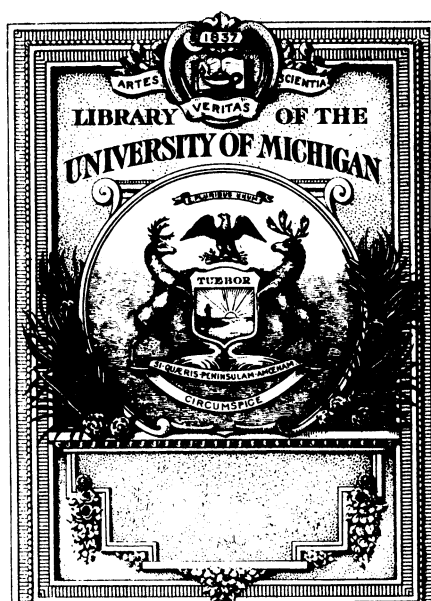
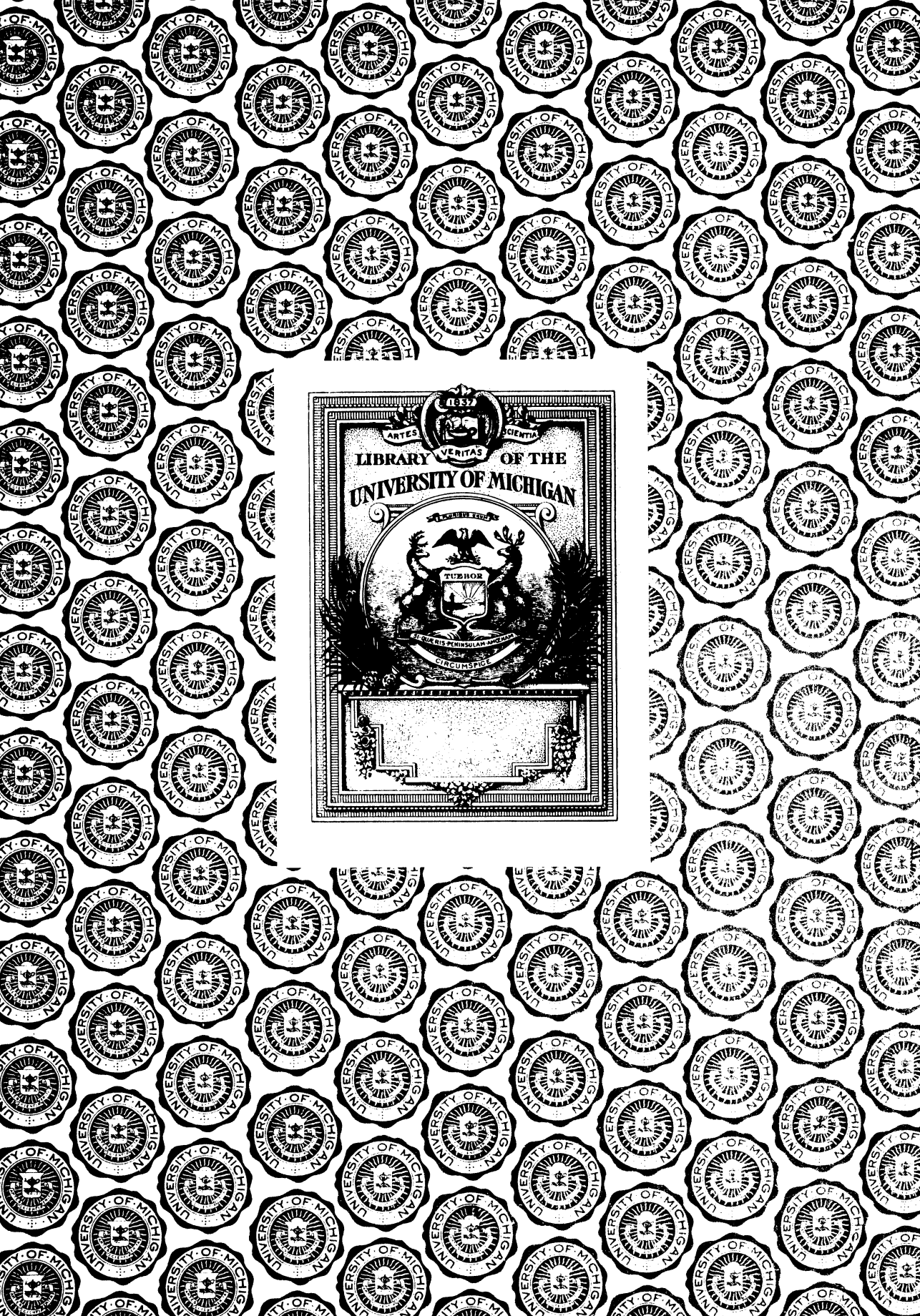
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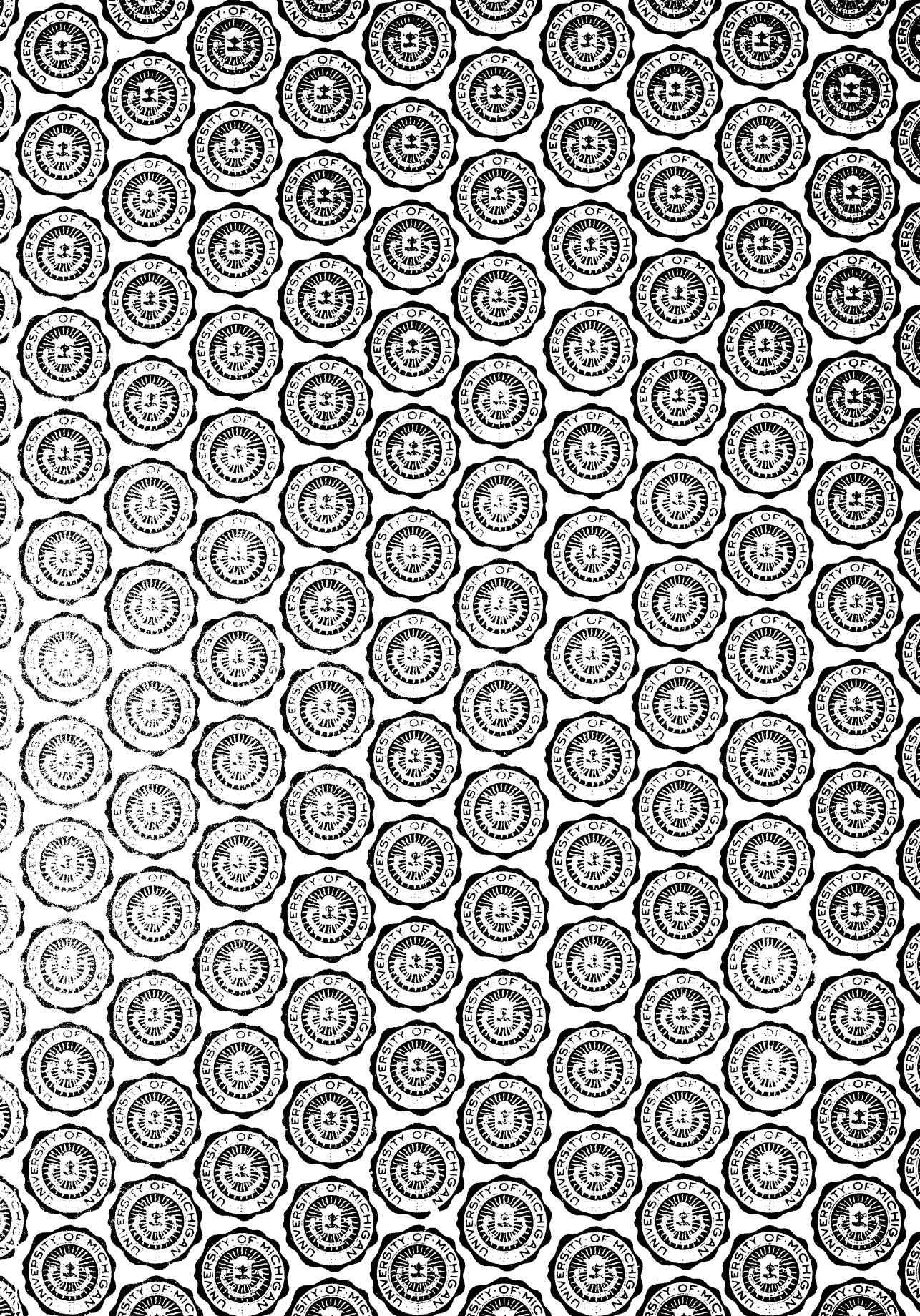
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VOLUME 32

JANUARY TO APRIL, 1927

WITH 50 PLATES AND 75 TEXT FIGURES



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1927

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THE PHILIPPINE JOURNAL OF SCIENCE

VOL. 32

JANUARY, 1927

No. 1

NITRIFYING POWER OF SOME PHILIPPINE SOILS

By M. M. ALICANTE

*Of the Division of Soils and Fertilizers, Bureau of Science
Manila*

INTRODUCTORY

This investigation deals with a certain biological property of Philippine soils. The following points of importance, directly concerned in crop production, are considered and made the basis of this investigation: (1) The correlation between the nitrifying capacity and the crop-producing power of some of the Philippine soils on which most of the important crops, such as rice, sugar cane, tobacco, and coconut are grown; (2) the comparative study of the nitrifying power of soils from different parts of the Islands; (3) the comparative study, under similar laboratory conditions, of the average nitrifying capacity of some of the Philippine soils, of the United States soils, and of the Hawaiian Territory soils; and (4) certain factors influencing the nitrifying power of some of the Philippine soils.

The old ideas regarding soil fertility have greatly changed since the development of the science of soil microbiology. According to earlier views, the decomposition of organic matter, the production of humus, and the conversion of nitrogen into nitrate in the soil were due to chemical action. Liebig in 1840 pointed out that the fertility of the soil was essentially dependent upon chemical processes. However, this view of Liebig was opposed by Pasteur, who demonstrated that biological action was mostly responsible for the decay and decomposition taking place in the soil. Some forty years ago the science of soil microbiology was yet in its infancy, and during its rapid development

numerous researches were conducted. The results from those classical experiments have shown that biological action is a dynamic force in soil fertility. After several years of experimentation, several investigators have come to the general conclusion that there exists a definite relationship between the nitrifying capacity and the crop-producing power of the soil.

Brief reference to a few of these investigations, which are considered fundamental in connection with this work, is here made.

HISTORICAL

Boussingault⁽⁴⁾ of France was the first to recognize the value of nitrification in relation to the fertility of the soil. Some years later, F. Löhnis⁽²⁰⁾ pointed out the close correlation between nitrification and the crop-producing power of the soil. Löhnis based his conclusion on the results of an experiment with a standard solution to which various soil extracts were added. After a certain period of incubation, the cultures were analyzed, and differences in nitrate production were noticed.

Vogel,⁽²⁶⁾ working with some German soils, found that the nitrifying power of the soil was directly correlated with its fertility; he therefore considered the importance of this power with regard to soil analysis.

Burgess,⁽⁷⁾ working with nine Hawaiian surface soils, all of which had been under cultivation to sugar cane and were soils of different fertility, reported that the degrees of nitrification, ammonification, and nitrogen fixation were in accordance with the fertility of the soils tested. Among the three biological tests, nitrification was found to give the most reliable results. The ammonification test was not suitable for differentiating the average Hawaiian soils except, in extreme cases, between very poor and very rich soils.

Brown,^(5, 6) upon testing the ammonifying and nitrifying powers of several plots, treated and untreated, found the results to be in direct correlation with the fertility of those plots. The results of the analysis also agreed with the crop yields. Gainey,⁽¹¹⁾ working with some Kansas soils, also found that nitrification has a direct bearing on the productivity of the soils.

Waksman⁽²⁷⁻³³⁾ of New Jersey found that, when ammonification was conducted in solution, the plot of higher fertility gave higher results in the absence of phosphates, but in the presence of phosphates reverse results were obtained. When the tests were conducted in the soil, it was noticed that acid soil of low

fertility had a greater accumulation of ammonia. He pointed out that the accumulation of ammonia in the soil after a certain period is not at all an index of soil fertility but merely indicates how incapable a certain soil is of transforming ammonia into nitrates.

On further study, he stated that in any bacteriological test of the soil, where results are sought in correlating the bacterial activities with the crop-producing power, a knowledge of the influence of the chemical conditions of the soil upon the microorganisms is indispensable. He demonstrated that, when ammonium sulphate was used for the nitrification test of an acid soil having a poor buffer action, the activity of the nitrifying bacteria was depressed. In a well-buffered acid soil, however, the use of ammonium sulphate enhanced nitrification. By using dried blood of higher quality or at high concentration (say 1 per cent) in a well-buffered soil, nitrification proceeded normally; but in a poorly buffered soil nitrification was depressed. He suggested, therefore, that for nitrification purposes ammonium sulphate should be used in the presence of a theoretical amount of calcium carbonate (210 milligrams for 30 milligrams nitrogen as ammonium sulphate) to neutralize all the nitric and sulphuric acids formed in the decomposition of ammonium sulphate. Dried blood or any nitrogenous organic materials of high quality, 0.1 per cent concentration at ten to fifteen days' incubation, or 0.25 per cent concentration at fifteen or fifteen and thirty days' incubation, should be used.

The results of the nitrification tests conducted on some experimental plots showed very conclusively that there is a definite correlation between the crop-producing power of the soil on the one hand and the number of the microorganisms and the nitrifying power of the soil on the other, due consideration being given, of course, to the effect of liming in the case of an acid soil.

Waksman, after a careful study of the effect of fertilizers upon the numbers of bacteria, reported that sodium nitrate stimulated the growth of bacteria and actomycetes, but depressed fungi; that ammonium sulphate, making the soil acid, favored the growth of fungi and depressed the action of bacteria and actomycetes; however, ammonium sulphate favored the growth of bacteria and actomycetes when applied with lime. He concluded that the number of microorganisms in the soil when determinations are carried out under proper conditions, provided due allowance be made for the variability of the methods

used and of the soils, can serve as one function for measuring the bacteriological conditions of the soil and the crop production.

Noyes and Conner,⁽²²⁾ studying the nitrate, nitrification, and bacterial content of five typical soils, noticed that the addition of calcium carbonate increased the nitrifying power of the acid soils tested; that fertilization increased the nitrification but not so much as did calcium carbonate; that the soils that had been saturated with water for ten months contained no nitrate and, when incubated with ammonium sulphate, nitrification did not take place.

The findings of J. G. Lipman and associates of New Jersey; E. J. Russell, H. B. Hutchinson and associates of Rothamsted, England; C. Hopkins, A. L. Whiting and associates of Illinois; W. P. Kelley of California; G. P. Given of Pennsylvania; and S. F. Ashby of England confirmed the general conclusion that there is a definite correlation between the microbiological activities and soil fertility.

SOILS AND METHODS OF SAMPLING

Samples representing the average types of soil devoted to sugar cane, rice, tobacco, abacá, and coconut were taken from different parts of the Islands. Most of the samples of sugar-cane soil were taken from Occidental Negros, which at present is the largest sugar district of the Islands. The samples from Occidental Negros were secured by me, through the courtesy of the sugar planters, and the samples from the other districts were obtained by the station men, by special arrangement with the plant-industry division of the Bureau of Agriculture. These samples were taken as follows:

Borings 16 centimeters deep were made with an auger in places where the soil is of the same general appearance as that of the whole field. At this depth the soil in one hectare would weigh 2,000,000 kilograms. At least fifteen such borings were made on every hectare of each field. The soils from these borings were mixed thoroughly and sampled in the usual manner. About 2 kilograms of each sample thus obtained were put in a soil bag, which was labeled and forwarded to the laboratory. According to Lipman and Martin's⁽¹⁷⁾ results, soil samples obtained by the auger method, as described above, and those obtained by the aseptic method (from a flamed vertical wall of a pit) showed insignificant differences only, in bacterial

counts and in ammonifying, nitrifying, and nitrogen-fixing powers.

EXPERIMENTAL

Preparation of soil samples.—All soils were air-dried, then passed through a 20-mesh sieve, and kept in 2,000-cubic-centimeter glass bottles, stoppered with corks. For chemical analyses the samples were passed through a 60-mesh sieve and kept in small glass bottles, also provided with corks. For nitrification purposes fresh samples were used, thus eliminating any factor that might affect the viability of the organisms concerned. According to Allison,⁽²⁾ storage and desiccation affect the numbers and activities of the soil organisms.

Nitrification.—Weighed portions of air-dried soil, each equivalent to 100 grams of water-free soil, were introduced into Erlenmeyer flasks of 300 cubic centimeters capacity. The carefully weighed materials for treating the samples were added to and thoroughly mixed with the soil. Water was then added to bring the moisture content of the sample up to 60 per cent, the amount recommended by Russell, Jones, and Bahrt⁽²⁵⁾ as the best for purposes of nitrification. The mixture was stirred to insure thorough distribution of moisture. Each flask was loosely stoppered with a cork. The treated samples were incubated at 28° C. for twenty-eight days. The moisture content was kept constant during the period of incubation. The soil samples were treated as follows:

1. No treatment given (control).
2. With 0.2 gram ammonium sulphate.
3. With 0.2 gram ammonium sulphate, and calcium carbonate slightly in excess of the amount required to neutralize the theoretical amounts of nitric and sulphuric acids produced during the decomposition and nitrification process of ammonium sulphate.
4. With copra cake equivalent to 34.8 milligrams, and 37.5 milligrams of nitrogen.
5. With copra cake equivalent to 34.8 milligrams, 37.5 milligrams of nitrogen, and calcium carbonate slightly in excess of the amount required to neutralize the acid reaction of the soil.

Nitrate determination.—Devarda's method, modified by Whiting⁽³⁴⁾ and associates, was used for the nitrate determination. The water-free samples were placed in 400-cubic-centimeter shaker bottles and 300 cubic centimeters of approximately 0.5 per cent hydrochloric acid were added to each sample. The

mixture was then shaken in a mechanical shaker for from one to three hours and allowed to settle overnight. Five grams of sodium peroxide were placed in an 800-cubic-centimeter Kjeldahl flask. Two hundred cubic centimeters of the acid extract of each sample were measured out and poured on the 5 grams of sodium peroxide and then placed in an 800-cubic-centimeter Kjeldahl flask. The contents of the flask were boiled down to 20 or 30 cubic centimeters, to expel any ammonia present. Two hundred cubic centimeters of nitrogen-free distilled water were then added, together with 0.5 gram Devarda's alloy (50 per cent aluminium, 45 per cent copper, and 5 per cent zinc), and the mixture was distilled for forty minutes and then collected in a flask containing standard sulphuric acid.

Total nitrogen.—The Kjeldahl method, modified to include nitrate nitrogen,¹ was used for the determination of the nitrogen of all the samples under investigation.

Determination of acidity (Hopkins's⁽¹²⁾ method for soil acidity.—One hundred grams of air-dried soil were placed in a 400-cubic-centimeter, wide-mouthed bottle, and 250 cubic centimeters of normal potassium nitrate solution were added. The bottle was stoppered and its contents continually shaken for three hours in a shaking machine and then allowed to stand overnight. One hundred twenty-five cubic centimeters of the clear supernatant liquid were drawn off and boiled for ten minutes, to expel the carbon dioxide. It was then cooled and titrated against a standard sodium hydroxide solution. The titration number was multiplied by 2.5 (the factor worked out by Hopkins) to give the acids present in 100 grams of dried soil.

A brief description made at the time of sampling each soil under study is here given. This description is important, because of the relation between certain field conditions and crop production. It was pointed out by Löhnis and Fred⁽²¹⁾ that any biological soil test has full value only when greenhouse and field experiments are taken into consideration. From the results of the experiments, I found that the conditions and nature of the soils, the kind and time of treatment, and the kinds of crops grown have a direct bearing upon the nitrifying capacity of the soil.

¹ Described in Bulletin 107 of the Association of Official Agricultural Chemists.

LOCATION AND DESCRIPTION OF SOIL SAMPLES

BATANGAS PROVINCE, LUZON

Laboratory No. 6.—Duras, Muson, Valentin's orchard. Planted to mandarin trees, productive since 1924 but not productive before that time. No fertilization. Surface soil, clay loam 49 centimeters deep. Slightly rolling. Good drainage.

Laboratory No. 5.—San Isidro, Santo Tomas, Mrs. Feliza's orchard. Planted to mandarin trees, very productive, healthy. No fertilization. Slightly rolling. Surface soil, clay loam, 62 centimeters deep. Good drainage; under cultivation for thirty to thirty-five years.

Laboratory No. 1.—Tanauan Citrus Station, block A. Planted to mandarin trees 20 years old, productive in 1919–1920 but practically barren now. No fertilization. Slightly rolling. Surface soil, clay loam, about 36 centimeters deep; under cultivation for about thirty-five to forty years.

Laboratory No. 2.—Tanauan Citrus Station, block B, east. Planted to mandarin trees 20 years old, bore light crops since 1919. No fertilization. Slightly rolling. Surface soil, clay loam, 38 centimeters deep; under cultivation for thirty-five to forty years.

Laboratory No. 3.—Tanauan Citrus Station, block B, west. Planted to mandarin trees 20 years old, bore light crops since 1919. Light application of complete fertilizer in 1923–1924, the last application in May, 1924. Slightly rolling. Surface soil, clay loam, 44 centimeters deep; under cultivation for thirty-five to forty years.

Laboratory No. 4.—Tanauan Citrus Station, block C. Planted to mandarin trees, bore heavily in 1919–1920, since then light crops were obtained. No fertilization. Slightly rolling. Surface soil, 34 centimeters deep; under cultivation for thirty-five to forty years.

Laboratory No. 7.—Tanauan Citrus Station, variety test plot. Planted to mandarin trees 1 to 3 years old, formerly the plot was occupied by productive trees. No fertilization. Slightly rolling. Surface soil, clay loam, 56 centimeters deep; under cultivation for thirty-five to forty years.

Laboratory No. 8.—Tanauan Citrus Station, miscellaneous plot. Planted to mandarin trees from 1 to 3 years old. No fertilization. Slightly rolling. Surface soil, clay loam, 35 centimeters deep; under cultivation for thirty-five to forty years.

MOUNTAIN PROVINCE, LUZON

Laboratory No. 18.—Bontoc, Calottit, semitemperate substation, field A, No. 1. Planted to nursery citrus plants. No fertilization. Rolling. Surface soil, clay, 4 centimeters deep. Under cultivation for four years.

Laboratory No. 19.—Bontoc, Calottit, semitemperate substation, field A, No. 2. Planted to coffee seedlings. No fertilization. Rolling. Surface soil, clay with rock, 45 centimeters deep. Under cultivation for four years.

Laboratory No. 20.—Bontoc, Calottit, semitemperate substation, field A, No. 3. Planted to nursery plants, mango stocks. No fertilization. Rolling. Surface soil, clay loam, 60 centimeters deep. Rocky subsoil.

Laboratory No. 21.—Bontoc, Calottit, semitemperate substation, field B, No. 1. Planted to hubar clover. No fertilization. Rolling. Surface soil, clay loam, rocky subsoil, about 30 centimeters deep.

Laboratory No. 22.—Bontoc, Calottit, semitemperate substation, field B, No. 2. Planted to loquats and peanuts. Fertilized with green manure. Rolling. Surface soil, clay loam, 90 centimeters deep, subsoil not so rocky.

Laboratory No. 23.—Bontoc, Calottit, semitemperate substation, field B, No. 3. Planted to early Crawford. Fertilized with green manure (leguminous plant). Rolling. Surface soil, clay loam, 60 centimeters deep. Subsoil not so rocky.

Laboratory No. 24.—Bontoc, Calottit, semitemperate substation, field B, No. 4. Planted to fruit trees, apples. Cowpeas used as green manure. Rolling. Surface soil, clay loam, 90 centimeters deep, subsoil rocky.

Laboratory No. 25.—Bontoc, Calottit, semitemperate substation, field B, No. 5. Planted to apples and peanuts. Leguminous green manure plowed under. Rolling. Surface soil, clay loam, 90 centimeters deep, rocky substratum.

Laboratory No. 26.—Bontoc, Calottit, semitemperate substation, field C, No. 1. Planted to fruit trees. No fertilization. Rolling. Surface soil, clay loam, 60 centimeters deep, substratum rock with clay. Newly cultivated.

Laboratory No. 27.—Bontoc, Calottit, semitemperate substation, field C, No. 2. Planted to fruit trees. No fertilization. Rolling. Surface soil, clay loam, 75 centimeters deep, substratum rock with clay. Newly cultivated.

Laboratory No. 28.—Bontoc, Calottit, semitemperate substation, field C, No. 3. Planted to fruit trees. No fertilization. Rolling. Surface soil, clay loam, 60 centimeters deep, substratum rocky. Newly cultivated.

Laboratory No. 29.—Bontoc, Calottit, semitemperate substation, field C, No. 4. Planted to fruit trees. No fertilization. Rolling. Surface soil, clay loam, 60 centimeters deep, rocky substratum.

Laboratory No. 30.—Bontoc, Calottit, semitemperate substation, field C, No. 5. Planted to fruit trees. No fertilization. Rolling. Surface soil, clay loam, 30 centimeters, with rocky substratum.

OCCIDENTAL NEGROS PROVINCE, NEGROS

Laboratory No. 49.—Bacolod, Hacienda Helvetia, owned by Jose de la Rama, fields 47, 48, 49, and 50. Planted to sugar cane. Fertilized with Sumatra and Corona No. 1, 500 kilograms per hectare. Plain. Surface soil, clay loam, very shallow. Drainage fair.

Laboratory No. 50.—Bacolod, Hacienda Helvetia, owned by Jose de la Rama, fields 58, 61, and 62. Planted to sugar cane. Fertilized with Sumatra and Corona No. 1, 500 kilograms per hectare. Slightly rolling. Surface soil, clay loam, rather shallow. Efficient drainage.

Laboratory No. 51.—Bacolod, Hacienda Helvetia, owned by Jose de la Rama, field 84. Planted to sugar cane. Fertilized with Sumatra and Corona No. 1. Thin surface soil, clayey in nature. Under cultivation for several years.

Laboratory No. 52.—Bacolod, Hacienda Socorro, owned by G. Villanueva, field 8. Planted to sugar cane, first year ratoon. Fertilized with Big Crop at the rate of 500 kilograms per hectare. Slightly rolling. Surface soil, locally called *abo-abo* soil.

Laboratory No. 57.—Bacolod, Hacienda Rosario, owned by Rafael Alunan. Planted to sugar cane. Fertilized with complete fertilizer at the rate of 500 kilograms per hectare. Slightly rolling. Deep surface soil, clay loam. Good drainage.

Laboratory No. 58.—Bacolod, Hacienda Madalagan, owned by S. Abasquez. Field prepared for cane. No fertilization. Plain. Deep surface soil, sandy clay.

Laboratory No. 67.—Isabela, Hacienda Constancia. Sugar cane fertilized with Big Crop and ammonium sulphate. Brown silt loam, surface soil about 30 centimeters deep. Plain.

Laboratory No. 68.—Isabela, Hacienda San Bonifacio. Sugar cane fertilized with Big Crop and ammonium sulphate. Surface soil about 20 centimeters deep. Plain.

Laboratory No. 69.—Isabela, Hacienda Alicante. Cane fertilized with Big Crop. Surface soil, clay, about 25 centimeters deep. Plain. Under cultivation for several years.

Laboratory No. 70.—Isabela, Hacienda Sto. Domingo. Cane fertilized with Big Crop and ammonium sulphate. Surface soil, clay, about 24 centimeters deep. Under cultivation for several years.

Laboratory No. 71.—Isabela, Hacienda Pasanghilan. Formerly rice land to be planted to sugar cane. No fertilization. Heavy clay, about 40 centimeters deep.

Laboratory No. 59.—La Carlota, Hacienda Caiñaman, owned by G. Villanueva. Planted to sugar cane. No fertilization. Sandy clay over clay and gravel. Under cultivation for several years.

Laboratory No. 60.—La Carlota, Hacienda Camanog, owned by G. Villanueva, field 1. Planted to sugar cane. No fertilization. Last year's yield was 4 tons per hectare. Surface soil rather thin, brown silt loam over red clay. Plain.

Laboratory No. 62.—La Carlota, Hacienda Camanog, owned by G. Villanueva, field 2. Cane with no fertilization. Last crop was 4 tons to the hectare. Surface soil, brown clay over gravel. Plain. Good drainage.

Laboratory No. 61.—La Carlota, Hacienda La Paz. Cane with no fertilization. Four tons to the hectare in last year's crop. Thin surface soil, clay. Plain. Drainage not so efficient.

Laboratory No. 84.—La Carlota Experiment Station, field A, No. 1. Planted to sugar cane; in previous years it was in corn. Treated with lime shell at the rate of 1,000 kilograms to the hectare. Clay loam, surface soil. Plain. Good drainage.

Laboratory No. 85.—La Carlota Experiment Station, field A, No. 2. Control plot, with cane, but previously in corn. No fertilization. Clay loam. Plain. Good drainage.

Laboratory No. 86.—La Carlota Experiment Station, fields C and D, No. 3. Planted to sugar cane, previously in corn. Fertilized with Alco at the rate of 500 kilograms per hectare. Clay loam. Plain. Good drainage.

Laboratory No. 87.—La Carlota Experiment Station, fields E, F, G, and I, No. 4. Planted to cane. No fertilization. Clay loam soil, about 37 centimeters deep. Plain. Good drainage.

Laboratory No. 88.—La Carlota Experiment Station, field H-1, No. 5. Planted to sugar cane and fertilized with mungo as green manure. Clay loam surface soil, about 33.2 centimeters deep. Plain. Efficient drainage.

Laboratory No. 89.—La Carlota Experiment Station, field H-2, No. 6. Planted to sugar cane and fertilized with cowpeas as green manure. Clay loam, surface soil, about 27.3 centimeters deep. Plain. Efficient drainage.

Laboratory No. 90.—La Carlota Experiment Station, field H-3, No. 7, control plot. Planted to sugar cane, with no fertilization. Clay loam surface soil, 23.3 centimeters deep. Plain. Efficient drainage.

Laboratory No. 91.—La Carlota Experiment Station, fields J and L, No. 8. Planted to sugar cane, with no fertilization. Clay loam surface soil, 26.4 centimeters deep. Plain.

Laboratory No. 92.—La Carlota Experiment Station, field T, No. 9. Planted to sugar cane, with no fertilization. Clay loam surface soil, 25.2 centimeters deep. Slightly rolling.

Laboratory No. 93.—La Carlota Experiment Station, field R-1, No. 10. Planted to sugar cane, with no fertilization. Clay loam surface soil, 24.8 centimeters deep. Plain.

Laboratory No. 94.—La Carlota Experiment Station, field R-2, No. 11. Sugar cane, with ammonium sulphate at the rate of 40 kilograms nitrogen per hectare. Surface soil clay loam, 25.2 centimeters deep.

Laboratory No. 95.—La Carlota Experiment Station, field R-3, No. 12. Cane, fertilized with Anaconda fertilizer at the rate of 25 kilograms phosphoric acid per hectare. Clay loam soil. Plain.

Laboratory No. 96.—La Carlota Experiment Station, field R-4, No. 13. Cane, fertilized with sulphate of potash at the rate of 30 kilograms potassium oxide per hectare. Clay loam soil. Plain.

Laboratory No. 97.—La Carlota Experiment Station, field R-5, No. 14. Cane, fertilized with slaked lime at the rate of 500 kilograms per hectare. Clay loam soil. Plain.

Laboratory No. 98.—La Carlota Experiment Station, field R-6, No. 15. Cane, fertilized with ammonium sulphate and Anaconda fertilizer at the rate of 40 kilograms of nitrogen and 25 kilograms of phosphoric acid per hectare. Clay loam soil. Plain.

Laboratory No. 99.—La Carlota Experiment Station, field R-7, No. 16. Cane, fertilized with ammonium sulphate and sulphate of potash at the rate of 40 kilograms nitrogen and 30 kilograms of potassium oxide per hectare. Clay loam soil, 23.2 centimeters deep.

Laboratory No. 100.—La Carlota Experiment Station, field R-8, No. 17. Cane, fertilized with ammonium sulphate and sulphate of potash at the rate of 25 kilograms nitrogen and 30 kilograms potassium oxide per hectare. Clay loam soil, 22.4 centimeters deep.

Laboratory No. 101.—La Carlota Experiment Station, field R-9, No. 18. Cane, fertilized with ammonium sulphate, Anaconda, and sulphate of potash at the rate of 40 kilograms nitrogen, 25 kilograms phosphorus pentoxide, and 30 kilograms potassium oxide per hectare. Clay loam soil, 24.2 centimeters deep.

Laboratory No. 102.—La Carlota Experiment Station, field R-10, No. 19. Cane, fertilized with ammonium sulphate, Anaconda, sulphate of potash and lime at the rate of 40 kilograms nitrogen, 25 kilograms phosphorus pentoxide, 30 kilograms potassium oxide, and 500 kilograms lime per hectare. Clay loam soil, 27.2 centimeters deep.

Laboratory No. 103.—La Carlota Experiment Station, field N, No. 20. Planted to corn previously, sugar cane since 1923. No fertilization. Surface soil, clay loam, 19.8 centimeters deep.

Laboratory No. 104.—La Carlota Experiment Station, field No. 21. Planted to abacá with no fertilization. Clay loam, 26.6 centimeters deep. Plain.

Laboratory No. 105.—La Carlota Experiment Station, field No. 22. Planted to coffee, with fertilization. Clay loam soil on rocky subsoil. Surface soil 14.4 centimeters deep. Rolling.

Laboratory No. 106.—La Carlota Experiment Station, field No. 23. Planted to coffee, with no fertilization. Clay loam soil on rocky subsoil. Surface soil 12.4 centimeters deep. Rolling.

Laboratory No. 64.—La Castellana, Hacienda Manzananao. Planted to sugar cane, first year. No fertilization. Surface soil about 80 centimeters deep. Slightly rolling.

Laboratory No. 63.—Maa Central, Hacienda Pangulayan. Planted to sugar cane, fertilized with Corona, Big Crop, and ammonium sulphate. Slightly rolling surface soil about 15 to 20 centimeters deep, impervious subsoil. Last year's yield 44 piculs.

Laboratory No. 65.—Maa Central, Hacienda Ibong. Planted to cane. Fertilized with Big Crop and ammonium sulphate. Surface soil about 20 centimeters deep. Last year's yield 80 piculs per hectare.

Laboratory No. 66.—Maa Central, Hacienda Zaragoza, Ledesma. Planted to sugar cane. Fertilized with ammonium sulphate and Big Crop. Surface soil about 20 centimeters deep, clay loam. Yield per hectare was 105 piculs.

Laboratory No. 72.—Maa Central, Hacienda Actividad. Planted to sugar cane. Fertilized with ammonium sulphate and Big Crop. Normal yield. Plain. Surface soil, 60 centimeters deep. Dark brown clay over sand.

Laboratory No. 73.—Maa Central, Hacienda Bulubugnay. Sugar cane, fertilized with Corona and Big Crop. Surface soil about 20 centimeters clay loam over impervious clay.

Laboratory No. 74.—Maa Central, Hacienda Bantolinao. Sugar cane, fertilized with ammonium sulphate and Big Crop, plain surface soil about 20 centimeters deep, red clay.

Laboratory No. 75.—Maa Central, Hacienda Zaragoza Montilla. Sugar cane, fertilized with ammonium sulphate and Big Crop. Gave normal yield. Slightly rolling surface soil 20 centimeters deep.

Laboratory No. 76.—Maa Central, Hacienda Buenavista. Sugar cane, fertilized with Big Crop and ammonium sulphate. Gave normal yield. Surface soil clay loam over impervious clay. Drainage rather poor.

Laboratory No. 77.—Maa Central, Hacienda Cubacubag. Sugar cane, fertilized with Big Crop and Corona No. 1. Normal yield was obtained. Surface soil clay loam over clay and gravel.

Laboratory No. 78.—Maa Central, Hacienda Yding. Planted to sugar cane. No fertilizer applied. Surface soil about 20 centimeters deep. Slightly rolling.

Laboratory No. 79.—Maa Central, Hacienda Progreso. Sugar cane, fertilized with Corona No. 1, Big Crop, and ammonium sulphate. Surface soil clay loam over clay and gravel.

Laboratory No. 80.—Maa Central, Hacienda Bonifacio and Progreso. Sugar cane; fertilized with Corona No. 1, Big Crop, and ammonium sulphate. Normal yield was obtained. Surface soil clay loam about 30 centimeters deep. Slightly rolling.

Laboratory No. 81.—Maa Central, Hacienda Begonia. Cane, fertilized with Big Crop and ammonium sulphate. Gave normal yield. Slightly rolling. Surface soil about 30 centimeters deep.

Laboratory No. 82.—Maa Central, Hacienda Maragandang. Cane, fertilized with ammonium sulphate, Big Crop, and Corona. Normal yield. Clay loam over clay and gravel.

Laboratory No. 56.—Manapla, Hacienda Maja. Being prepared for cane, planted to cane previously. Not fertilized. Deep soil, red clay. Fairly good drainage.

Laboratory No. 53.—Philippine Hawaiian, Hacienda Basag, owned by C. Locsin, lime-experiment plot, control. Planted to cane, first-year ratoon. Fertilized with 500 kilograms ammonium sulphate per hectare. Plain. Surface soil clay loam about 35 centimeters deep. Fairly good drainage. Yield 88 piculs of sugar per hectare.

Laboratory No. 54.—Philippine Hawaiian, Hacienda Basag, owned by C. Locsin, lime-experiment plot, with lime. Planted to cane, first-year ratoon. Treated with lime and fertilized with 500 kilograms ammonium sulphate. Surface soil clay loam 35 centimeters deep. Plain. Good drainage.

Laboratory No. 55.—Hacienda Badyong owned by V. Mappa, virgin soil. Uncultivated for several years. Deep surface soil, locally called abo-abo. Plain.

PANGASINAN PROVINCE, LUZON

Laboratory No. 9.—Rosales Rice Experiment Station, No. 1, variety test. Planted to lowland rice. Mungo and cowpeas were previously grown. No fertilization. Plain. Surface soil silt loam 30 centimeters deep. Good drainage. Under cultivation for several years.

Laboratory No. 10.—Rosales Rice Experiment Station, No. 2, propagation plot. Planted to lowland rice, previously grown to corn, mungo, and cowpeas. No fertilization. Plain. Surface soil silt loam 30 centimeters deep. Good drainage. Under cultivation for several years.

Laboratory No. 11.—Rosales Rice Experiment Station, No. 3, fertilizer-test plot. Planted to lowland rice. Mungo and cowpeas used as green manure. Fertilizer was not yet applied. Plain. Surface soil silt loam 30 centimeters deep. Good drainage. Under cultivation for several years.

Laboratory No. 12.—Rosales Rice Experiment Station, No. 4, dry-season plot. Planted to upland rice. Two crops are raised a year. No fertilization. Plain. Surface soil, silt loam, over 30 centimeters deep. Excellent drainage. Under cultivation for several years.

Laboratory No. 13.—Rosales Rice Experiment Station, No. 5, rotation plot. Rice rotated with sweet potatoes, gabis, and napier grass. No fertilization. Surface soil silt loam 30 centimeters deep. Plain. Drainage good.

RIZAL PROVINCE, LUZON

Laboratory No. 14.—Alabang Rice Station, No. A, paddy field. Planted to lowland rice. No fertilization. Plain. Surface soil clay 15 centimeters. Poor drainage.

Laboratory No. 16.—Alabang Rice Station, No. B-1, extension field. Planted to lowland rice. No fertilization. Surface soil clay 14 centimeters deep. Poor drainage.

Laboratory No. 17.—Alabang Rice Station, field C. Planted to sugar cane. No fertilization. Plain. Surface soil clay 29 centimeters deep. Poor drainage.

DISCUSSION OF TABLES 1, 2, AND 3

TABLE 1

Table 1 gives the nitrification results of all the soils analyzed. The first column gives the laboratory number of each soil sample, and the rest of the table is divided into series and each series is discussed separately. All the figures in this table are the results of duplicate tests, and were reported only when the difference between two determinations was not higher than 0.5 milligram of nitrate nitrogen.

Series I.—The figures in the first column indicate the quantity of nitrate nitrogen produced in 100 grams of each sample of untreated soil after it had been incubated under optimum conditions of moisture and temperature. The figures in the second column indicate the percentage of nitrogen converted into nitrate in each sample. The object in carrying out the experiment under this series was to find out how efficient certain soils are in converting their own nitrogen into nitrate, given proper aëration and optimum conditions of moisture and temperature.

Series II.—The experiment under this series consisted in adding ammonium sulphate to each sample of soil. The object was to get some idea as to how much of the nitrogen of ammonium sulphate could be converted into nitrate after a short period of incubation, but particularly to find out whether or not it would be profitable to apply ammonium sulphate to some of the soils under study. The effect of the treatment on the original reaction of the soil was also noted. The first column of the series presents the amount in milligrams of nitrate nitrogen produced per culture, and the second column the percentage of the added nitrogen nitrified.

Series III.—In this series, each soil sample was treated with ammonium sulphate and calcium carbonate. The amount of calcium carbonate was computed on the basis of the theoretical amounts of nitric and sulphuric acids formed from the decomposition of ammonium sulphate during the process of nitrification according to Waksman.⁽²⁹⁾ The original reaction of the soil was taken into account in the application of calcium carbonate. The purpose of the experiment was to learn the stimulating effect of lime in the form of calcium carbonate upon the nitrifying power of the soil, and also the maximum speed of nitrification from the easily nitrifiable source of nitrogen.

Series IV.—Dried blood has been used by most investigators in running nitrification tests; but, owing to lack of supply of this material in the laboratory where this work was conducted, copra cake was used in its place. Copra cake is a by-product of coconut-oil extraction. If the oil is extracted by hydraulic pressure, the oil content of the cake is from 7 to 8 per cent; in factories where other methods of extraction are used, the oil content is 12 to 15 per cent. The nitrogen content of copra cake is, on the average, about 3 per cent. Copra cake was used instead of other nitrogenous materials, because it is a home product and is easily obtained by the farmer. The purpose in treating the several soils under investigation with this material was to find out how much of its nitrogen content could be converted into available form under normal conditions, and also to ascertain whether the nitrate produced would be sufficient for the immediate need of heavy feeder crops such as sugar cane and corn.

Series V.—Each soil sample was treated with both copra cake and calcium carbonate. In every case calcium carbonate was applied in an amount slightly in excess of what the soil reaction would call for. With the application of calcium carbonate it was expected to increase the nitrifiability of copra cake and to get its full value as a nitrogenous fertilizer.

DISCUSSION OF RESULTS, TABLE 1

Batangas Province, soils grown to citrus trees.—The results of nitrification tests on citrus soils show a direct correlation between high nitrifying power and high productivity. In the case of ammonium sulphate treatment, samples 5 and 6, which were obtained from the most productive orchards, nitrified 42.30 per cent and 32.56 per cent, respectively, of the nitrogen added, whereas samples 1, 2, 3, and 4, from the unproductive orchards, nitrified only 15.77 per cent, 26.66 per cent, 21.28 per cent, and 20.77 per cent, respectively. This greater nitrification power of samples 5 and 6 as compared with that of other samples (except 4) was also observed in the case of copra cake. Samples 5 and 6 nitrified 41.66 per cent and 26.14 per cent, respectively, of the nitrogen of the copra cake, and sample 4, 32.75 per cent, whereas samples 1, 2, and 3 nitrified much smaller portions. Physically, however, the make-up of soils 4 and 6 is approximately the same, and chemically both soils contained the same amount of acid, which was equivalent to 120

TABLE 1.—Nitrification results.

TANAUAN CITRUS STATION AND NEIGHBORING ORCHARDS, BATANGAS PROVINCE

Soil No.	Series I, blank incubated.		Series II, ammonium sulphate.		Series III, ammonium sulphate and calcium carbonate.		Series IV, copra cake.		Series V, copra cake and calcium carbonate.	
	Nitrate nitrogen, per 100 grams culture.	Original nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.
	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.
1.....	3.60	3.00	5.50	15.77	31.00	79.48	3.90	11.20	14.90	42.81
2.....	3.10	2.58	10.40	26.66	26.90	69.97	4.90	14.08	7.50	21.55
3.....	2.50	2.35	8.30	21.28	22.30	63.58	6.40	18.39	16.10	46.26
4.....	1.00	.92	8.10	20.77	32.60	83.58	11.40	32.75	16.60	47.70
5.....	4.00	2.58	16.50	42.30	34.70	88.97	14.50	41.66	13.60	39.08
6.....	2.50	2.10	12.70	32.56	28.50	73.07	9.10	26.14	17.50	48.81
7.....	2.10	1.85	12.40	31.79	28.20	72.28	9.70	27.87	16.90	48.56
8.....	1.60	1.50	10.40	26.66	26.40	65.12	6.70	19.25	18.40	52.87

ROSALES RICE STATION, PANGASINAN PROVINCE

9.....	5.00	4.76	17.40	47.18	25.90	66.41	11.60	30.46	14.30	41.09
10.....	5.70	5.09	26.90	66.43	33.90	86.92	16.80	48.24	16.10	46.26
11.....	6.50	6.07	15.50	39.58	30.40	77.94	9.30	26.74	9.70	25.00
12.....	9.30	6.37	21.20	54.35	29.70	76.92	7.80	22.35	2.70	7.75
13.....	4.70	Trace	21.10	54.10	32.70	83.84	9.70	28.90	5.50	12.92

ALABANG RICE STATION, RIZAL PROVINCE

14.....	5.25	5.70	3.50	8.75	4.75	11.87	1.50	3.99	6.50	17.30
16.....	9.25	9.43	0.75	1.87	7.50	18.75	-----	-----	0.75	2.18
17.....	9.00	8.90	1.00	2.50	26.00	65.00	3.00	7.38	7.00	18.63

CALOTTIT STATION, BONTOC, MOUNTAIN PROVINCE

18.....	1.75	1.92	0.75	1.87	24.75	61.87	4.50	11.98	10.75	28.62
19.....	3.00	3.08	0.75	1.87	2.75	6.87	-----	-----	-----	-----
20.....	3.00	2.56	6.50	16.25	25.75	64.37	6.25	16.62	15.25	40.60
21.....	7.50	4.28	8.50	21.25	13.00	32.50	2.50	6.65	9.75	25.95
22.....	5.75	4.32	1.50	-----	17.50	43.75	3.00	-----	4.50	11.99
23.....	4.50	3.88	0.50	1.25	35.20	88.00	6.75	17.97	13.75	33.94
24.....	6.25	5.34	4.50	11.25	35.95	89.87	4.25	11.31	6.50	17.30
25.....	4.50	4.15	4.25	10.87	31.25	78.15	0.75	1.99	14.00	37.27
26.....	7.00	9.07	6.00	15.00	32.25	80.62	3.25	8.68	14.50	38.65
27.....	3.75	5.34	7.25	18.12	31.75	79.37	5.00	13.31	7.50	19.70
28.....	4.00	4.65	2.00	5.00	22.50	56.25	4.25	11.31	14.50	38.60
29.....	7.00	7.95	2.25	-----	38.00	95.00	0.75	-----	5.00	-----
30.....	4.50	5.33	2.25	5.76	13.50	33.75	0.25	0.66	1.50	3.99

TABLE 1.—*Nitrification results—Continued.*

LAMAQ STATION, BATAAN PROVINCE

Soil No.	Series I, blank incubated.		Series II, ammonium sulphate.		Series III, ammonium sulphate and calcium carbonate.		Series IV, copra cake.		Series V, copra cake and calcium carbonate.	
	Nitrate nitrogen, per 100 grams culture.	Original nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.
	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.
31	5.25	6.56	10.50	26.25	10.50	26.25	16.50	43.92		
32	5.25	5.09	9.75	24.37	27.50	68.75	14.50	38.59	19.75	52.58
33	4.50	9.37	16.25	46.25	37.25	92.55	15.50	41.26	17.50	46.59
34	11.25	15.20	11.50	28.75	30.00	75.62	2.00	5.99	14.00	37.96
35	Trace		13.75	34.37	39.25	98.12	17.50	46.59	17.75	47.25
36	5.50	13.75	5.50	14.10	7.75	19.37	13.75	36.60	16.50	43.92
37	9.75	12.50	6.00	15.38	8.00	20.00	7.25	19.30	13.25	35.30
38	4.75	7.20	11.00	28.12	34.75	85.62	15.00	39.93	15.00	39.93
39	4.25	4.88	14.00	35.00	33.25	83.12	17.25	45.92	20.75	55.24
40	4.25	6.53	4.75	11.87	27.00	60.75	7.25	19.30	6.50	17.30
41	4.50	5.00	9.75	24.37	36.50	91.25	11.75	31.28	18.00	47.92
44	4.50	5.76	9.50	23.75	31.25	78.12	11.75	31.28	16.75	47.47
45	4.25	4.72	7.00	17.50	37.25	93.12	12.50	33.28	27.00	71.83
48	6.00	7.79	5.50	14.10	21.75	54.37	5.50	14.90	7.75	20.60

SUGAR-CANE PLANTATIONS, OCCIDENTAL NEGROS PROVINCE

49	4.75	6.41	2.25	5.76	15.75	40.38	8.25	21.99	17.75	47.25
50	1.87	2.96	1.88	4.80	4.36	11.21	3.41	9.11	10.61	29.61
51	5.00	6.11	5.50	14.10	24.25	61.17	10.00	26.62	15.00	39.93
52	Trace		2.50	6.41	5.75	14.74	2.50	6.66	2.50	6.65
53	2.50	1.47	10.50	27.02	24.00	61.53	11.25	29.68	18.12	48.27
54	3.00	2.97	6.87	16.34			18.00	22.35	21.50	51.24
55	4.37	0.89	0.88	2.25	2.88	7.30	0.88	2.25	8.63	23.67
56	2.62	2.54	1.87		7.13	18.28	2.25		6.25	16.70
57	4.62	4.01	5.38	13.73	37.75	94.10	16.25	43.23	26.88	71.54
58	5.00	6.25	2.50	6.41	35.25	90.38	14.00	35.93	13.00	34.64
59	8.37	8.04	14.50	37.17	34.13	87.50	12.50	30.61	13.38	35.62
60	7.62	6.45	16.55	42.18	36.50	93.59	16.88	44.96	22.00	58.57
61	2.50	1.90	6.87	17.61	29.00	74.35	7.50	21.27	10.50	34.61
62	4.50	3.78	13.31	31.73	34.75	89.10	13.25	35.27	16.67	44.26
63	3.75	2.55	2.50	6.43	3.25	8.33	2.00	5.32		
64	6.50	3.00	8.75	22.43	36.75	94.23	4.50	11.98	17.50	46.59
65	4.50	3.48	0.25	0.64	17.25	42.30	4.25	11.31	11.75	31.28
66	Trace		4.50	11.53	22.50	57.69	8.25	21.96	16.75	44.65
67	1.75	1.86	7.00	17.50	34.75	86.87	8.50	22.66	18.00	47.92
69	2.00	2.19	19.50	48.75	37.25	93.12	17.50	46.59	17.50	46.59
70	1.75	1.50	12.50	31.25	38.50	96.25	14.25	37.98	14.25	37.98
71	1.75	0.73	15.50	37.58	30.00	75.00	11.50	30.61	18.50	49.25
72	4.50	2.68	2.50	6.24	25.50	62.50	1.50	6.65	13.00	34.64
74	6.25	1.43	27.25	68.12	33.00	82.50	16.25	43.26	11.25	29.96
76	Trace		12.25	30.62	35.50	88.75	15.50	41.26	27.00	71.88
77	3.25	2.87			36.00	90.00	1.75	4.65	5.75	15.30
78	Trace		6.00	15.00	20.00	50.00	10.00	26.62	20.00	53.27
79	2.50	2.38	2.50	6.25	28.00	70.00	5.00	13.31	6.75	18.00
81	3.25	1.31			19.50	48.75	3.50	9.31	13.50	41.93

TABLE 1.—Nitrification results—Continued.

LA CARLOTA STATION, OCCIDENTAL NEGROS PROVINCE

Soil No.	Series I, blank incubated.		Series II, ammonium sulphate.		Series III, ammonium sulphate and calcium carbonate.		Series IV, copra cake.		Series V, copra cake and calcium carbonate.	
	Nitrate nitrogen, per 100 grams culture.	Original nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.	Nitrate nitrogen.	Added nitrogen nitrified.
	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.
84.....	2.60	1.09	9.00	16.41	11.80	30.23	2.70	7.84	6.90	18.89
85.....	1.00	0.45	15.00	38.46	30.70	78.72	11.90	39.94	18.30	53.19
86.....	1.10	0.55	12.50	32.05	29.90	76.66	13.80	38.50	19.50	55.17
87.....	2.20	1.27	13.00	33.33	32.10	79.23	12.70	35.74	18.80	54.64
88.....	1.70	1.01	16.50	42.30	-----	-----	13.60	36.20	16.40	48.27
89.....	2.00	1.54	18.40	47.18	36.00	92.30	14.00	40.00	21.60	60.17
90.....	3.00	1.87	14.50	37.07	29.70	76.15	3.80	11.04	4.00	11.54
91.....	2.50	1.03	17.50	44.87	27.50	70.51	3.50	10.11	5.50	15.98
92.....	2.10	-----	16.70	42.82	35.40	85.69	7.30	18.31	4.80	13.95
93.....	4.30	1.50	16.30	41.79	30.80	78.97	5.20	15.11	6.10	17.73
94.....	2.60	0.92	22.00	56.41	33.40	85.64	15.80	42.09	16.70	48.83
95.....	3.00	0.87	22.80	58.46	33.20	82.56	16.00	46.50	16.50	47.96
96.....	3.80	1.00	22.00	55.12	33.40	85.64	14.30	36.38	15.40	41.00
97.....	3.10	0.93	19.70	50.51	33.60	86.41	14.40	38.33	14.80	39.40
98.....	2.50	0.84	19.40	49.74	33.90	86.92	16.00	42.59	17.00	45.26
99.....	3.10	0.91	23.50	58.71	33.00	84.61	13.40	35.68	14.90	40.20
100.....	3.40	0.99	15.30	39.31	31.40	80.25	14.10	36.12	15.70	41.79
101.....	2.20	0.55	22.40	57.43	34.80	89.23	15.50	41.00	17.30	46.05
102.....	4.60	0.14	15.10	38.71	29.40	75.38	13.20	35.17	13.00	34.62
103.....	3.20	1.19	21.65	55.51	34.30	87.94	12.40	35.04	14.20	37.80
104.....	3.50	1.52	14.20	36.66	31.40	80.00	13.70	37.00	16.10	42.86
105.....	5.00	1.91	15.00	38.46	32.25	82.69	12.80	37.20	13.10	36.20
106.....	3.40	1.16	16.00	41.02	32.00	83.58	15.30	40.75	12.90	37.50

kilograms calcium carbonate per hectare. Presumably the buffer actions of these two soils, with regard to acid and alkali, are the controlling factors, which may account for the difference in results. According to Waksman's(29) findings, ammonium sulphate could be applied to a well-buffered acid soil without the activities of the nitrifying bacteria being hindered; but, in a poorly buffered acid soil, the effect of the acid practically stops nitrification. In this connection the views of Ruprecht and Morse(23) with regard to the application of ammonium sulphate are worthy of consideration. They claimed that the injurious effect was due to the formation of the sulphates of magnesium, iron, and aluminium, rather than to the acids produced. When ammonium sulphate and copra cake were

applied with calcium carbonate, the nitrifying powers of the soils were accelerated to a much higher degree. Undoubtedly these soils had a sufficient number of nitrifying bacteria and could be made to nitrify under normal conditions.

Rosales Rice Station soils.—One of the most striking points presented in the table is the high nitrifiability of ammonium sulphate as compared to that of copra cake in soils of this section of Pangasinan Province. When ammonium sulphate and copra cake were applied separately, 52.32 per cent of the nitrogen of the former was nitrified, whereas of the latter only 31.33 per cent on an average was nitrified. When the same materials were applied with calcium carbonate, an increase in nitrate production was observed in the case of ammonium sulphate, but there was a decrease in the case of copra cake. In general, all the soils tested nitrified very efficiently the original nitrogen content and the nitrogen of the materials used, such as ammonium sulphate and copra cake. When ammonium sulphate was applied in combination with calcium carbonate, the nitrate production increased from 52.32 per cent to 78.40 per cent; but when copra cake was used with calcium carbonate the nitrate production decreased from 31.33 per cent to 26.60 per cent. Since these soils were only slightly acidic in reaction, the decrease in nitrate production was due to the lime added, which affected the activities of the organisms concerned in the process of nitrification. This effect, however, was not noticed with ammonium sulphate, because sulphuric acid was being produced during the decomposition of the sulphate, which undoubtedly sufficed to counteract the alkalinity of the calcium carbonate.

Alabang Rice Station soils.—The nitrification results obtained from the study of the soils in this station were very low, the highest for ammonium sulphate being 8.75 per cent, and the lowest 1.89 per cent. For copra cake the highest was 7.38 per cent, and the lowest negative. Upon the addition of calcium carbonate to these materials, higher nitrification results were obtained. The physical analyses of these soils showed, without exception, a high content of clay. Seemingly, the physical effect derived from the application of lime stimulated the activities of the bacteria concerned in the process of nitrification. The poor physical properties of these soils, and this low content of nitrogen, phosphorous, potassium, and other, less-important elements may account for the low nitrifying power of these soils.

Calottit, Semitemperate Station soils.—The high nitrate production found in all of these soils after a period of incubation was due to the previous application of leguminous plants as green manure, and the addition of nitrogen, in the form of either ammonium sulphate or copra cake, did not increase their nitrifying power to a noticeable extent. When either ammonium sulphate or copra cake, alone, was applied to these soils only a small portion of their nitrogen content was nitrified; but, when each was applied in combination with calcium carbonate, a larger portion of their nitrogen was converted into nitrate. The principal reasons for the low nitrification of the nitrogen of the added materials were the presence at the time of sampling of sufficient quantities of nitrogenous materials the nitrogen of which is easily nitrified and, possibly, the insufficient numbers of nitrifying organisms present. From the physical standpoint, these soils offer the best conditions for optimum nitrification. Their percentage of clay is much lower than that of other soil separates.

Lamiao Station soils.—The efficiency of the soils in this station in converting their own original nitrogen into available form was higher than that of any other soils tested. The nitrogen of both ammonium sulphate and copra cake, either applied alone or in combination with calcium carbonate, was highly nitrified. This result seems to indicate that these soils are capable of converting the nitrogen of any nitrogenous material into available form, thereby insuring a sufficient supply of nitrate for the maximum crop yield.

Soils from different plantations of Occidental Negros.—After a careful examination of the nitrification results of each of the individual fields, it was found that low nitrification was closely associated with the poor physical condition of the soil. For example, sample 56 was found, upon physical analysis, to contain 44.89 per cent clay, and the percentage of gravel was also high. When ammonium sulphate was applied alone to this soil, it was not nitrified after an incubation of twenty-eight days at 28° C. The same result was obtained in the case of copra cake. The addition of calcium carbonate to ammonium sulphate and copra cake induced nitrification to only a small degree. As this soil was also acid in reaction, the use of the calcium carbonate made possible the reduction of its active acids and improvement of its physical condition. However, the plantation soils tested were in general found to be efficient in convert-

ing the nitrogen of ammonium sulphate and copra cake into available form. Taking into consideration the methods of cultivation, the manner of application, and the kinds of fertilizers used, the results correlate with the average yields of the fields, judged from my observation on the stand of cane at the time of sampling.

La Carlota Experiment Station soils.—Of all the Negros soils tested, those from this station showed the highest nitrifying power in general; but the ability of these soils to nitrify their own original nitrogen was low. The probable reasons are the following: (a) These soils have been under intensive cultivation for a number of years and, by continued cropping, have become toxic to the nitrifying bacteria and (36, 21) been rendered inactive; (b) the nitrogenous materials which these soils contained were not easily broken up and the twenty-eight-day period of incubation allowed in the experiment was not sufficient to bring about their maximum decomposition; (21) and (c) corn was previously grown in those fields which, being a heavy feeder crop, depleted the soil of its essential elements.

TABLE 2

The figures in Table 2 give the average results of nitrification for each locality or district. The object in preparing this table was to show the degree of variation in the nitrifying power of the soils from different parts of the Islands. In spite of the heavy application of commercial fertilizers in the sugarcane districts of Occidental Negros, the ability of the soils in those districts to convert the original nitrogen into available form was less than that of the soils of other districts where different crops, such as rice, tobacco, coconut, abacá, citrus, etc., are grown. Nevertheless, the data show that the sugarcane districts are rather efficient in nitrifying ammonium sulphate and copra cake, and possibly other nitrogenous fertilizers.

Alabang soils show poor nitrifying power. The figure 8.01 under the column "per cent of original nitrogen nitrified" does not necessarily mean that these soils are highly efficient in converting their original nitrogen into available form. The result of the physical analysis indicates that these soils are very retentive, as they contain a high percentage of clay. Such soil characteristic is generally found to facilitate a high accumulation of ammonia. Consequently, when these soils were subjected to oxidation under favorable conditions, the ammonia already present was converted into nitrate. It was observed that dur-

TABLE 2.—Average nitrification for each district.

Location.	Series I, blank incu- bated.		Series II, ammonium sulphate.		Series III, ammonium sulphate and calcium car- bonate.		Series IV, copra cake.		Series V, copra cake and cal- cium carbonate.	
	Nitrate nitro- gen per 100 grams culture.	Original ni- trogen nitrif- ied.	Nitrate nitro- gen.	Added nitro- gen nitrified.	Nitrate nitro- gen.	Added nitro- gen nitrified.	Nitrate nitro- gen.	Added nitro- gen nitrified.	Nitrate nitro- gen.	Added nitro- gen nitrified.
	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.	mg.	P. ct.
1. Batangas Prov- ince, Tanauan Experiment Station and other citrus or- chards.....	2.55	2.11	10.16	25.97	28.82	74.50	8.32	23.66	15.18	43.45
2. Bataan Province, Lamao Exper- iment Station....	5.28	8.05	9.62	21.67	27.28	67.64	12.00	31.97	16.19	43.37
3. Mountain Prov- ince, Bontoc, Ca- lottit Exper- iment Station....	4.82	4.76	3.93	7.86	24.73	62.27	3.70	10.04	10.50	26.96
4. Occidental Negros Province, La Carlota Exper- iment Station...	2.40	10.1	17.45	44.34	31.42	79.19	12.64	33.43	14.34	39.88
Plantations.....	3.93	3.19	6.95	20.30	26.76	63.92	9.24	23.69	13.59	39.35
5. Pangasinan Prov- ince, Rosales Rice Exper- iment Station....	6.24	5.57	20.42	52.32	30.52	78.40	11.04	31.33	9.26	26.60
6. Rizal Province, Alabang Rice Experiment Sta- tion.....	7.83	8.01	1.75	4.37	12.75	31.87	2.25	5.68	4.75	12.70

ing the process of nitrification, the formation of ammonia was slower than the oxidation of ammonia to nitrate.(21) Tanauan, Rosales, and Lamao soils, in general, are rather efficient in their nitrifying power. The organisms concerned are made active by the addition of calcium carbonate. Of the soils of these three stations, the Lamao soil shows highest efficiency in nitrifying its own original nitrogen content, the percentage being 8.05. Calottit, a semitemperate district of the Islands, has lower nitrifying power as compared with the nitrifying power of the soils from other places, except those from Alabang station. As Calottit is located in a district of higher elevation where the land is rolling in character, the fertility of its soils has been depleted to a considerable extent, due to the excessive washing from yearly

precipitation and, according to Waksman's⁽²⁷⁾ investigation, the numbers and activities of the soil organisms are in direct correlation with the fertility. This, as one factor, may account for the low nitrifying power of the soils from this district.

TABLE 3

Table 3 gives the average results of the nitrification tests for the Philippine, the Hawaiian, and the United States soils. The Philippine soils were subjected to similar laboratory conditions as were the soils of the other two countries. The difference, however, lies in one particular treatment, in which copra cake was used for the Philippine soils and dried blood for the Hawaiian and the United States soils. As far as the nitrifiability of these two materials was concerned very little difference had been observed. I assumed that such variation would not materially influence the comparison of the nitrifying power of the soils of the three countries.

The original nitrogen in the Philippine soils examined undergoes a greater degree of nitrification than does that in the Hawaiian soils, but very much less than that in the United States soils. When ammonium sulphate was added, the Philippine soils nitrified 25.26 per cent of the added nitrogen, while the United States soils nitrified 23.75 per cent. The Hawaiian soils nitrified almost twice as much as did either of the other two countries. In the case where the nitrogen added was derived from an organic source, the Philippine soils showed a lower nitrification power than did the Hawaiian, but approximately the same as the United States soils. It is logical, however, to expect that the difference in the activities of soil bacteria would occur between the Philippine and the United States soils, because the climatic conditions of these two countries are extremely different; but the difference was very pronounced between the Hawaiian and the Philippine soils, climatic conditions being similar in many respects, and therefore it must be assumed that factors other than climatic influence were responsible for this difference in results.

From my personal observation during my short stay in the Hawaiian Territory, traveling from one island to another, the soils are all of volcanic origin, highly loaded with the oxides of aluminium and iron; organic matter is not very abundant. In general the soils are porous, offering excellent aëration.⁽⁷⁾ After several qualitative tests in the fields with the solution of potassium sulphur cyanate⁽⁹⁾ most of the soils were found only

TABLE 3.—Average nitrifying power of some of the Philippine soils as compared to those of Hawaii and the United States.

Country.	Series I, blank incubated.		Series II, ammonium sulphate.		Series III, ammonium sulphate and calcium carbonate.		Series IV, copra cake.		Series V, copra cake and calcium carbonate.	
	Nitrate nitrogen per 100 grams culture.	Original nitrogen nitrified.	Nitrate nitrogen per 100 grams culture.	Added nitrogen nitrified.	Nitrate nitrogen per 100 grams culture.	Added nitrogen nitrified.	Nitrate nitrogen per 100 grams culture.	Added nitrogen nitrified.	Nitrate nitrogen per 100 grams culture.	Added nitrogen nitrified.
Philippine Islands.	4.72	4.55	7.75	25.26	26.04	65.39	8.45	22.82	11.79	33.18
Hawaiian Territory.	3.06	0.44	21.78	48.90	-----	-----	^a 12.82	^b 29.00	^b 21.29	^b 49.90
United States (every state and territory included)	15.96	14.62	11.23	23.75	-----	-----	^a 26.53	^a 19.65	-----	-----

^a Dried blood.^b Dried blood and calcium carbonate.

slightly acid. In practically all the places visited, drainage was found to be very efficient; hardly any stagnant water or water-logged soil was noticed. On the other hand, the greater number of Philippine soils are residual, containing a considerable amount of organic matter. The amount of iron and aluminium oxides is not so high as that found in Hawaiian soils. Most of the soils are clayey, underlined with an impervious stratum, giving unsatisfactory drainage. Judging from the above description, therefore, the Hawaiian soils offer the most favorable conditions for maximum nitrification.

In general, the nitrifying power of the Philippine soils tested for ammonium sulphate and copra cake, with or without the addition of calcium carbonate, is considerably lower than that of either the Hawaiian or the United States soils. However, the original nitrogen in the Philippine soils examined is more readily nitrified than is that in the soils from the two countries cited. This may be attributed to the following factors:

a. The physical make-up of Philippine soils is clayey in nature and underlain with an impervious stratum, which renders drainage and aëration unsatisfactory.

b. The prolonged and extreme drying of the soils which occurs during the summer months, reduces very materially the number and activities of the soil bacteria. In previous work, (1) I demonstrated conclusively the effect of prolonged desiccation, under laboratory conditions, upon the viability of legume bacteria, azotobacter, and *Bacillus radiobacter*.

c. Most of the Philippine soils are acidic in reaction.

It was noticed that in all normal soils, ammonium sulphate was nitrified sooner than was copra cake. This result, of course, is not surprising; it simply illustrates the number of stages taking place during the process of nitrification. In the conversion of ammonium sulphate into nitrate only the following three stages are concerned, and these stages are easily carried on without the expense of surplus energy: (a) The breaking down of ammonium and sulphate radicals into ammonium hydroxide and sulphuric acid; (b) the oxidation of ammonia to nitrite; and (c) the further oxidation of nitrite to nitrate. However, in the case of copra cake, at least four important steps are necessary, namely: (a) The breaking down of the organic matter from complex protein compounds into simpler ones; (b) the hydrolysis of nitrogen radical to ammonium hydroxide; (c) the oxidation of this ammonia to nitrite; and (d) the further oxidation of nitrite to nitrate.

The possible biological reactions concerned in the decomposition of ammonium sulphate and copra cake are:

Ammonium sulphate—

1. $(\text{NH}_4)_2\text{SO}_4 + 2\text{HOH} \rightarrow 2\text{NH}_4\text{OH} + \text{H}_2\text{SO}_4$.
2. $\text{NH}_4\text{OH} + 3\text{O} \rightarrow \text{HNO}_2 + 2\text{HOH}$.
3. $\text{HNO}_2 + \text{O} \rightarrow \text{HNO}_3$.

Copra cake—

1. Sample $\xrightarrow{\text{broken down by molds and cellulose bacteria.}}$ $\left\{ \begin{array}{l} \text{Simple protein} \\ \text{compounds contain-} \\ \text{ing nitrogen.} \end{array} \right.$
2. (Protein compounds) $\text{R}-\text{N} \xrightarrow[\text{ammonifiers}]{\text{hydrolyzed by}}$ $\text{R and NH}_4\text{OH}.$ ²
3. $\text{NH}_4\text{OH} \xrightarrow[\text{Nitrosomonas}]{\text{oxidized by}}$ HNO_2 .
4. $\text{HNO}_2 \xrightarrow[\text{Nitrobacter}]{\text{oxidized by}}$ HNO_3 .

In almost all cases, the application of calcium carbonate increased the nitrifying power of the soils. The object of using

² It has been observed by Löhnis and Fred that the decomposition of organic matter to ammonia is a difficult one, and time is an important consideration in the rate of decomposition.

calcium carbonate is twofold; namely, to correct the physical condition of the sticky soils and to neutralize their acidity. From the practical point of view the latter is the more important and worthy of consideration. The use of calcium carbonate or lime with the idea of correcting the physical condition of the soil is prohibitive in agricultural practice, because a heavy application is required to give any appreciable effect. Since neutralizing acidity is the more important function of calcium carbonate, it should be used only when the soil is acid. Although Burgess(8) noticed increase in nitrification from the use of lime carbonate in alkaline soil, he attributed this increase to the physical rather than to the chemical effect. It should be remembered also that during the process of nitrification a strong acid is liberated, making the reaction of the medium very unfavorable to the nitrifying organisms; and unless this acid is neutralized their activities stop, resulting in the delay of nitrification. Hence the presence of calcium carbonate in the soil is very necessary; it encourages nitrification and accelerates to the maximum the activities of the nitrifying bacteria.

SUMMARY

1. The results obtained in the treatment of citrus soils constitute conclusive evidence that nitrification is an index of crop production. Soils from productive orchards showed higher nitrifying power than did soils from unproductive orchards.

2. In general, soils devoted to sugar cane converted their original nitrogen into available form more slowly than did those devoted to rice, abacá, tobacco, coconut, citrus, etc. The average nitrogen for sugar-cane soils was 2.10 per cent, while for the other soils it was 5.70 per cent.

3. It was found that the physical property of the soil has an important bearing on its nitrifying power. Soils containing a high percentage of clay nitrified either the original or the added nitrogen very poorly.

4. The addition of calcium carbonate to most of the soils accelerated their nitrifying power, resulting in high production of nitrate; but its application to the Rosales soils proved injurious to the activities of the organisms concerned, and this may account for the low nitrifying power of those soils.

5. In general, ammonium sulphate was converted into nitrate faster than was copra cake. The changes which these materials undergo during the process of nitrification account for the difference in the rate of decomposition.

6. On the average, the nitrifying power of some of the Philippine soils was lower than that of the Hawaiian. Possibly the factors responsible for this difference are the physical and chemical effect of the soil properties, and also the effect of climatic conditions upon the activities of the soil organisms.

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FREE TOXIN IN THE BLOOD DURING THE COURSE OF TETANUS TOXÆMIA

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Considerable work has been done on the resorption of tetanus toxin with the particular object in view of learning whether the toxin is resorbed by way of the nerves or by way of the blood stream.

Gumprecht, Goldscheider, Zupnik,² and others claimed that in general tetanus the toxin is conveyed to the central nervous system by the blood stream; but Mayer and Ramson³ maintained that the toxin is transported by peripheral nerves.

Sawamura,⁴ experimenting on rabbits, proved that the form of tetanus depends on the amount of injected toxin and the region where the injection is made. If tetanus toxin is given directly into the muscle or subcutaneously where the skin is directly attached to the muscle, ascending tetanus will develop; but, if the toxin is given in a place where there is no muscle, descending tetanus will take place.

The present experimental study was undertaken as a supplement to a clinical test performed by one of us on a patient suffering from chronic tetanus.

A young boy, 11 years of age, developed rigidity of the muscles of the face, of the trunk, and of the extremities. There was no recent injury to which the infection could be attributed. The rigidity increased gradually. Diagnosis of tetany was made. A consulting physician was called after the malady had lasted for about two months and he requested a laboratory test, rather to convince the parents that the child was suffering from tetanus and not from tetany than to establish the diagnosis.

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² Kolle W., und H. Hetsch, *Die Experimentelle Bakteriologie und die Infektionskrankheiten*, VI. Auflage, 1: 559.

³ Arch. f. Exp. Path. u. Pharm. 49 (1903).

⁴ Experimentelle Studien zur Pathogenese und Serumtherapie des Tetanus. Arbeiten a.d. Inst. z. Erforschung der Infektionskrankh. in Bern, H. 4, Jena, G. Fischer (1909).

At the time one of us saw the patient there was a pronounced opisthotonus and typical "risus sardonicus" present, rigidity of all the muscles of the extremities and of the trunk muscles, the form and insertions of which were plainly visible upon inspection. None of the usual symptoms of tetany were present, so that the diagnosis of tetany could be discarded. The patient presented a typical picture of tetanus with attacks of clonic spasm which occurred particularly at night and in which the diaphragm was evidently involved. Upon close questioning of the intelligent parents it was learned that the boy acquired a wound on his foot from a cut previous to his sickness and that he had had decayed teeth for some time. No evidence of the alleged wound could be found at the time of examination. There being no clue to the search for the focus of infection we suggested a test for free toxin. Five cubic centimeters of blood were withdrawn from a vein and placed in a test tube containing sterile sodium citrate. The entire amount of blood obtained by venepuncture was injected subcutaneously into a guinea pig to enable us to obtain the maximum effect.

The guinea pig, 300 grams body weight, developed typical symptoms of tetanus on the second day and died the fourth day after injection.

It is evident that the patient, several days before death, harbored in the circulating blood a considerable amount of free tetanus toxin after two and a half months of illness, since 5 cubic centimeters of his full blood contained at least one minimal lethal dose for a guinea pig of 300 grams body weight.

In the literature touching the present question a most interesting reference was found, that of Madsen,⁵ who demonstrated the presence of tetanus toxin in the blood of a horse five days before the onset of the symptoms.

The present experimental study was made for the purpose of demonstrating how far the presence of tetanus toxin can be demonstrated in the blood in the course of tetanus toxæmia.

Experiments with sterile toxin, which allowed an approximate quantitative estimation of the amount of toxin circulating in the blood of the experimental animal, were performed.

CHOICE OF EXPERIMENTAL ANIMALS

Guinea pigs were used as recipients of the tetanus toxin to be searched for in the blood stream. Guinea pigs were se-

⁵ Tetanusgift im Serum eines Pferdes, fünf Tage vor dem Ausbruch des Tetanus, Zentralbl. f. Bakt. 46 (1908).

lected for our work because of the type of tetanus they develop after subcutaneous injection of tetanus toxin in the supraumbilical region, and also for the reason that they are the most susceptible of small experimental animals. As Kolle⁶ states, the same amount of tetanus toxin is the minimal lethal dose for 1 gram of mouse, 12 grams of horse, 8 grams of guinea pig, 2 grams of goat, or 1.5 grams of rabbit. Mice were also used on account of their small size and susceptibility to tetanus toxin.

EXPERIMENTS ON ANIMALS WITH TETANUS TOXIN

A ripe, or well-settled, tetanus toxin was used, the original minimal lethal dose of which was 0.00007 cubic centimeter for a 300-gram guinea pig.

The general plan of the experiments was to inject decreasing doses of toxin into experimental animals and to withdraw the blood from them. The withdrawn blood was placed in a definite amount of sodium citrate and injected subcutaneously or intramuscularly into smaller animals, such as guinea pigs and mice. The details are evident from Table 1.

DISCUSSION

It is evident from Table 1 that the minimal lethal dose of the toxin in question was 0.0005 cubic centimeter, since a guinea pig of 300 grams body weight that received this dose subcutaneously died within four days after injection.

A guinea pig of 820 grams weight that received five hundred minimal lethal doses for a standard-weight guinea pig harbored, within twenty-four hours after the injection, in 2 cubic centimeters of its blood enough free tetanus toxin to kill a 235-gram guinea pig within forty-eight hours.

A guinea pig of standard weight (300 grams) which received two hundred minimal lethal doses harbored, within twenty-four hours after the injection, at least one minimal lethal dose for a guinea pig of its own weight in 0.5 cubic centimeter of its full blood. A 300-gram guinea pig that received forty minimal lethal doses for a guinea pig of standard weight harbored in 0.5 cubic centimeter of its blood, within twenty-four hours after the injection, at least one minimal lethal dose for a mouse of 15 grams body weight.

A standard-weight guinea pig, injected subcutaneously with ten minimal lethal doses for a guinea pig of standard weight,

⁶ Kolle und Hetsch, *Die Experimentelle Bakteriologie und die Infektionskrankheiten*, VI. Auflage, 1: 548-549.

TABLE 1.—Showing the results of animal tests for free tetanus toxin in the circulating blood.

[s, slight stiffness; ss, distinct stiffness; sss, pronounced stiffness; D2 dead on the second day; D3, dead on the third day; D4, dead on the fourth day; D6, dead on the sixth day; D13, dead on the thirteenth day.]

Guinea pig No.	Body weight.	Subcutaneous amount.		Bled after injection.	Amount of blood injected into hind leg of guinea pig or mouse.			Days.					
					Blood.	Animal.	Weight of animal.						
		cc.	Minimal lethal doses.	Hrs.			g.	1	2	3	4	5	6 or more.
1.	820	0.25	500	24	cc.	Guinea pig.	235	s	D2				
2.	300	0.3	600	24	0.5	do.	300	s	sss	sss	D4		
3.	300	0.2	400	24	0.5	do.	300	s	ss	sss	sss	D13	
4.	300	0.1	200	24	0.5	do.	300	s	ss	D3			
5.	300	0.03	60	24	0.5	Mouse.	15		ss	D3			
6.	300	0.02	40	24	0.5	do.	15		ss	D3			
7.	300	0.01	20	24	0.5	do.	15		ss	sss	sss	D6	
8.	300	0.005	10	24	0.5	do.	15		s	ss	ss	ss	
9.	300	0.0025	5	24	0.5	do.	15				ss	ss	
10.	300	0.001	2	24	0.25	do.	15						
11.	300	0.0005	1	24		Guinea pig.	300		s	ss	D4		
12.	300	0.0001	0.5	24		do.	300	(*)	(*)	(*)	(*)	(*)	
13.	300	0.00005	0.1	24		do.	300	(*)	(*)	(*)	(*)	(*)	

* Lived with symptoms.

harbored, within twenty-four hours, in 0.5 cubic centimeter of its blood enough tetanus toxin to produce symptoms of tetanus in a mouse of 15 grams within twenty-four hours after the intramuscular injection into the mouse, while a guinea pig of standard weight that received subcutaneously five minimal lethal doses for a guinea pig of standard weight harbored enough tetanus toxin in 0.5 cubic centimeter of its blood, within twenty-four hours after the injection, to produce typical tetanus symptoms on the fourth day in a mouse of 15 grams body weight.

As can be seen from Table 1, it so happened that one 300-gram guinea pig received two hundred minimal lethal doses and, within twenty-four hours after the injection, 0.5 cubic centimeter of its full blood contained one minimal lethal dose. In other words, the guinea pig received 0.1 cubic centimeter of the toxin subcutaneously and at least 0.0005 cubic centimeter was circulating in every 0.5 cubic centimeter of its full blood. If we calculate the amount of total blood of the guinea pig of 300 grams body weight as approximately 20 cubic centimeters, fifty minimal lethal doses were circulating in its blood within twenty-four hours, which is one-fourth of the total amount of toxin injected.

From unpublished experiments performed some years ago by A. P. Hitchens and Otto Schöbl, we know that tetanus antitoxin injected into horses subcutaneously will appear in its maximum amount toward the end of the third or the fourth day after injection, and will not exceed 40 per cent of the calculated concentration in the blood. It is, therefore, at once evident that the resorption of the tetanus toxin is much quicker than the resorption of the tetanus antitoxin, particularly the concentrated globulin, which was used in our unpublished experiments. Theoretically, two hundred minimal lethal doses should be neutralized by two units of tetanus antitoxin, whereas of the two hundred minimal lethal doses subcutaneously injected fifty minimal lethal doses appeared in the circulating blood within twenty-four hours. The result of subcutaneous injection of two units would be that only 0.8 of a unit would circulate in the blood of the animal, and that not until the third day after the injection of the antitoxin. Therefore, in a case such as ours, in order to neutralize the tetanus toxin that circulates in the blood twenty-four hours after inoculation

with tetanus toxin, at least ten antitoxic units would have to be injected two days previous to the injection of two hundred minimal lethal doses.

In view of the fact that some sera are being tested with a view of learning their curative value and, furthermore, in view of the fact that tetanus toxin and antitoxin allow approximate mathematical calculation, this information is of practical value to anyone who wishes to test sera for their curative value.

ANILIDES AND TOLUIDES OF CHAULMOOGRIC ACID

By PILAR HERRERA-BATTEKE

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INTRODUCTION

The pioneer work on the constituents of chaulmoogra oil and the chemistry of the fatty acids present in it was carried out by Power and his associates.¹ They prepared the methyl and ethyl esters and a number of salts of chaulmoogric acid, one of the active constituents of chaulmoogra oil. Perkins² prepared the propyl, butyl, and amyl esters of the mixed chaulmoogra acids. Herrera-Batteke and West³ prepared the capryl, allyl, phenyl, ortho, meta, and para cresol esters of chaulmoogric acid. Aside from these and a few mercury derivatives, very little has been done on the line of derivatives of chaulmoogric acid.

Since chaulmoogric acid is a compound of high molecular weight it is much easier to prepare its amide than either the acid chloride or anhydride. Power and Gornall⁴ prepared chaulmoogramide from the acid chloride of chaulmoogric acid, following the general method of Aschan.⁵

The anilide of chaulmoogric acid may be prepared readily by fusing one mole of chaulmoogramide with a little over one mole of aniline at 195 to 200° C. Instead of aniline the toluidines may be used with equal success. By using substituted anilines the corresponding substituted anilides are obtained.

EXPERIMENTAL DATA

The chaulmoogra oil used in this investigation was obtained from the variety of chaulmoogra seeds known as *Hydnocarpus alcalae* C. de Candolle, a tree indigenous to Albay, Philippine Islands, and known locally as *dudu dudu*. A sample of the oil

¹ Power, F. B., and F. H. Gornall, Journ. Chem. Soc. Trans. 85¹ (1904) 838 and 851; Barrowcliff, M., and F. B. Power, *ibid* 91¹ (1907) 557.

² Philip. Journ. Sci. 24 (1924) 621.

³ Philip. Journ. Sci. 31 (1926) 161-168.

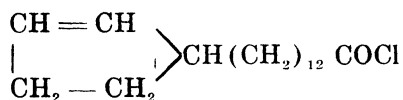
⁴ Journ. Chem. Soc. Trans. 85¹ (1904) 851.

⁵ Ber. 31 (1898) 2344.

was kindly presented to this laboratory by Dr. G. A. Perkins, chief chemist of Culion Leper Colony.

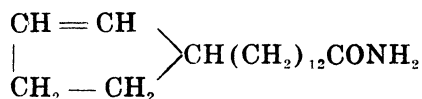
Chaulmoogric acid, $C_{17}H_{31}COOH$, was prepared according to the directions of Herrera-Batteke and West.⁶ The acid was crystallized from 95 per cent ethyl alcohol and then from petroleum ether (boiling point below $75^{\circ}C.$) to precipitate the resins, and finally from 95 per cent ethyl alcohol. Colorless glistening plates, which melted at $68^{\circ}C.$, were obtained.

ACID CHLORIDE OF CHAULMOOGRIC ACID



Sixty grams of chaulmoogric acid were placed in a round-bottomed flask provided with a reflux condenser and warmed until the acid melted; 16 grams of phosphorous trichloride were then added slowly from a dropping funnel and mixed thoroughly with the acid. The mixture was warmed with a small flame. The reaction was finished in fifteen minutes. Phosphorous acid separated at the bottom of the flask and by cooling with ice water became viscous, while the acid chloride remained as a light supernatant liquid. The acid chloride was poured into a dropping funnel and used in the preparation of chaulmoogramide.

CHAULMOOGRAMIDE



In preparing chaulmoogramide concentrated ammonium hydroxide was poured into a 1-liter beaker immersed in a freezing mixture. The acid chloride of chaulmoogric acid was allowed to drop slowly from a dropping funnel into the cold ammonia, while the mixture was stirred continuously. The amide separated out as a white crystalline precipitate. The amide was filtered and washed with water until the washings were no longer alkaline. It was then dried on sheets of filter paper, after which it was crystallized from 95 per cent ethyl alcohol. Colorless crystals, which melted at $104^{\circ}C.$, were obtained. The yield was 80 per cent. The amide was soluble in ethyl alcohol but insoluble in petroleum ether.

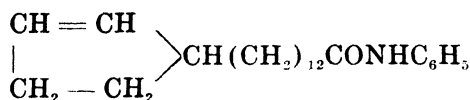
⁶ Philip. Journ. Sci. 31 (1926) 161-168.

The nitrogen content of the amide and of the other nitrogen compounds recorded in this paper was determined by Meulen's catalytic method.⁷

Analysis of chaulmoogramide.

Calculated for $C_{18}H_{33}ON$	Nitrogen. Per cent.
Found:	5.02
I	5.08
II	5.01

CHAULMOOGRANILIDE



In preparing chaulmoogranilide 40 grams of chaulmoogramide were placed in a round-bottomed flask provided with an air condenser and heated in an oil (crisco) bath to a temperature of 130° C.; 16 grams of freshly distilled aniline were added and mixed with the amide. The mixture was then heated at a temperature of 195 to 200° C. for five hours. The reaction started at 195° C., at which temperature ammonia gas was given off. The melt was then poured into a beaker of ice water and the anilide separated out as a crystalline mass. The anilide was filtered, washed thoroughly with water, and crystallized several times from alcohol (95 per cent) containing a small quantity of animal charcoal. It was obtained as colorless plates which melted at 89° C. The yield was 90.4 per cent. The anilide dissolved readily in ether, chloroform, and carbon tetrachloride, but was practically insoluble in petroleum ether and water. When hydrolyzed with sodium hydroxide and then heated with a few drops of chloroform and a slight excess of alcoholic potash, the odor of phenyl isocyanide was detected.*

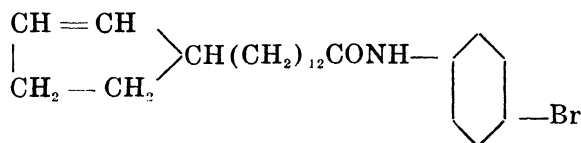
Analysis of chaulmoogranilide.

Calculated for $C_{24}H_{37}NO$	Nitrogen. Per cent.
Found:	3.94
I	3.86
II	3.70

⁷ Recueil des Travaux Chimiques des Pays-Bas 43 (1924) 643.

* Hofmann's test for primary amines.

CHAULMOOGRA PARA BROM-ANILIDE

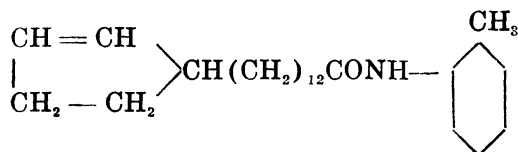


Nineteen and a half grams of chaulmoogramide were placed in a round-bottomed flask provided with an air condenser and heated in an oil (crisco) bath until the amide melted; 12 grams of para brom-aniline were then added and the mixture heated at 225° C. for half an hour. Ammonia gas was evolved. The reaction product was poured into a beaker of ice water and the precipitated brom-anilide was filtered off and washed with water. By repeated crystallization from 95 per cent ethyl alcohol, containing a small quantity of norit, colorless plates which melted sharply at 100° C. were obtained. They were soluble in ether, chloroform, and acetone, but practically insoluble in petroleum ether. The yield was 52.7 per cent. Qualitative tests showed the presence of carbon, hydrogen, nitrogen, and bromine.

Analysis of chaulmoogra para brom-anilide.

Calculated for $\text{C}_{24}\text{H}_{38}\text{ONBr}$		Nitrogen. Per cent.
Found:		3.23
I		3.38
II		3.29

ORTHO CHAULMOOGRATOLUIDE



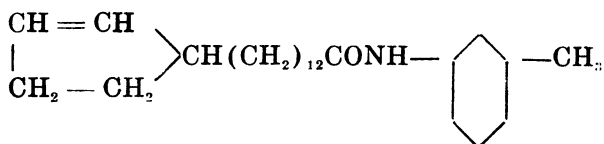
In the preparation of ortho chaulmoogratoluide 30 grams of chaulmoogramide were placed in a round-bottomed flask provided with an air condenser and heated on an oil (crisco) bath to 130° C. to melt the amide; 14 grams of freshly distilled ortho toluidine were then added and the mixture heated at a temperature of 230 to 235° C. for one and a half hours. Ammonia gas was evolved. The reaction product was then poured with constant stirring into a beaker of ice water. The toluidine precipitated out as a crystalline mass. This was filtered and washed with distilled water until free from ammonia. It was then crystallized repeatedly from 95 per cent ethyl alcohol,

containing a small quantity of norit, until the melting point was constant. The toluidide was obtained as colorless plates, which melted at 95° C. The yield was 85.7 per cent. The toluidide was soluble in the usual organic solvents, but insoluble in petroleum ether.

Analysis of ortho chaulmoogratoluide.

Calculated for $C_{28}H_{30}ON$	Nitrogen. Per cent.
Found:	3.79
I	3.67
II	3.77

META CHAULMOOGRATOLUIDE

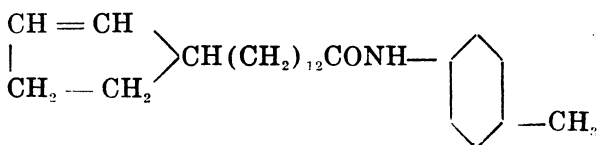


Forty grams of chaulmoogramide were placed in a round-bottomed flask provided with an air condenser and heated on a wire gauze until the amide melted; 18 grams of freshly distilled meta toluidine were then added and the mixture boiled gently for two hours. The apparatus was disconnected and the reaction product poured with constant stirring into a beaker of ice water. A colorless precipitate of the toluidide was obtained. This was filtered, washed with distilled water, and dried between sheets of filter paper. It was then crystallized from 95 per cent ethyl alcohol containing a small quantity of norit. Colorless plates melting at 88° C. were obtained. The toluidide was soluble in alcohol, ether, and chloroform, but practically insoluble in petroleum ether and water. The yield was 58.6 per cent.

Analysis of meta chaulmoogratoluide.

Calculated for $C_{28}H_{30}ON$	Nitrogen. Per cent.
Found:	3.79
I	3.89
II	3.76

PARA CHAULMOOGRATOLUIDE



Forty grams of chaulmoogramide and 18 grams of para toluidine were mixed in a round-bottomed flask provided with an air condenser and boiled gently on a wire gauze for two hours. The reaction product was then poured with constant stirring into a beaker of ice water. The precipitated toluidide was filtered, washed, and crystallized from 95 per cent ethyl alcohol containing a small quantity of norit. Colorless plates, melting at 100° C., were obtained. The yield was 51 per cent. The toluidide was soluble in alcohol, acetone, and chloroform, but practically insoluble in petroleum ether.

Analysis of para chaulmoogratoluide.

	Nitrogen. Per cent.
Calculated for $C_{25}H_{39}ON$	3.79
Found:	
I	3.68
II	3.63

SUMMARY

1. Anilides and toluides of chaulmoogric acid can be prepared in fairly good yield from chaulmoogramide by treating it with the calculated quantity of amine base.

2. The following new derivatives of chaulmoogric acid have been prepared: Chaulmoogranilide, chaulmoogra para bromanilide, ortho chaulmoogratoluide, meta chaulmoogratoluide, and para chaulmoogratoluide.

ACKNOWLEDGMENTS

I wish to express my thanks to Dr. A. P. West for his kind and helpful interest in this work and to Miss Paz Soriano for assistance in making the analyses.

AN ODORIFEROUS OIL AND TWO NEW LINOLIC TETRABROMIDES FROM PHILIPPINE LUMBANG OIL

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Philippine lumbang (candlenut) oil is a drying oil which is used in making paints, varnishes, and similar products.¹ A preliminary investigation of lumbang oil was made by West and Montes,² who showed that it consists principally of a mixture of unsaturated glycerides (linolenic, linolic, and oleic). The mixed unsaturated acids, obtained from the glycerides, were separated from each other by converting them into their bromo-derivatives³ which may be separated by solvents. The following four bromo-derivatives were thus prepared from lumbang oil:

Linolenic hexabromide, melting point, 178.5° C.

Linolic tetrabromide, crystals, melting point, 112 to 113° C.

Linolic tetrabromide (oil).

Oleic dibromide (oil).

In making this investigation the idea was to separate out the principal constituents. Only a very small quantity of oil was used in making the analysis, and no attempt was made to isolate minor constituents which may represent only a small proportion of the oil.

Some experiments carried out by us recently indicated that other constituents might be obtained from lumbang oil, in addition to those noted by West and Montes in their preliminary investigation. The results of this work showed that an odoriferous oil and also two crystallized tetrabromides (melting point

¹ West, A. P., and F. L. Smith, Bull. P. I. Bur. Forestry 24 (1923).

² Philip. Journ. Sci. 18 (1921) 619.

³ Lewkowitsch, J., Chemical Technology and Analysis of Oils, Fats, and Waxes 1 (1921) 585.

below 112° C.) could be obtained from lumbang oil. These low-melting tetrabromides are different from the linolic tetrabromide (melting point, 112 to 113° C.) prepared by West and Montes.

Takahashi⁴ prepared linolic tetrabromide (melting point, 114° C.) from soy-bean oil. When this tetrabromide was reduced to linolic acid and again brominated, he obtained three isomeric tetrabromides, which he designated as follows:

Compound.	Melting point. °C.
Alpha tetrabrom stearic acid (Alpha linolic tetrabromide)	113.5–114
Beta tetrabrom stearic acid (Beta linolic tetrabromide)	59–60
Gamma tetrabrom stearic acid (Gamma linolic tetrabromide)	(liquid)

In order to distinguish the isomeric tetrabromides obtained from lumbang oil, we used the nomenclature adopted by Takahashi for the corresponding compounds obtained from soy-bean oil.

EXPERIMENTAL PROCEDURE

Odoriferous oil.—Preliminary experiments showed that, when lumbang is steam distilled, apparently none of the oil distills over. If the aqueous distillate is extracted with ether, dehydrated, filtered, and the ether removed by distilling, a few cubic centimeters of a colorless oil are obtained. This oil has an intense lumbang odor and appears to be the substance that gives the characteristic odor to lumbang oil. The oil is very soluble in ether and dissolves when treated with a sufficient quantity of water.

In order to prepare a larger quantity of this odoriferous oil various methods were tried. The best method seemed to be to precipitate the acids, which occur as glycerides in the oil, in the form of zinc soaps. The zinc soaps were then separated by filtering and the filtrate extracted with ether, to obtain the odoriferous oil. Several batches of oil were treated in this manner.

This method was carried out according to the following procedure: The lumbang oil (600 grams) was saponified with aldehyde-free alcoholic potassium hydroxide in the usual manner. The alkali solution used for saponification was prepared

⁴ Journ. Tokyo Chem. Soc. 40 (1919) 233.

by treating 180 grams of potassium hydroxide with 80 cubic centimeters of water, after which 800 cubic centimeters of aldehyde-free alcohol were added. The mixture of oil and alkali solution was heated on a water bath (reflux) for about four hours to complete the saponification. The mixture was then cooled to room temperature and treated gradually with glacial acetic acid until the solution was about neutral to phenolphthalein which was used on a spot plate as an outside indicator. The mixed potassium soaps were treated with an alcoholic solution of zinc chloride containing a slight excess of the calculated amount of zinc chloride. Since the best grades of zinc chloride are sometimes contaminated with zinc oxide, it is advisable to ascertain how much zinc oxide is present in the zinc chloride. The estimated amount of zinc chloride is then treated with alcohol and the zinc oxide impurity removed by filtering. After adding the zinc chloride solution the mixture was heated on a water bath (reflux) for about two hours and then divided into four equal portions, each of which was poured into a separate large beaker. The mixtures were cooled in ice water and diluted with a sufficient amount of alcohol in order that the crystallized zinc salts might be filtered easily. The zinc salts were removed by filtering and the filtrate was concentrated, to obtain a second crop.

The filtrate from the second crop of zinc salts was poured into water, stirred thoroughly, and filtered. The aqueous filtrate was then extracted with ether. The precipitated zinc salts were washed thoroughly with water. The wash waters were extracted with ether and this ether extract was added to the first extract. The combined ether extracts were dehydrated with sodium sulphate, filtered, and the ether was removed by distilling. The crude odoriferous oil, which had a brown color, was distilled on an oil bath. It passed over as a colorless oil (boiling point, 80 to 95° C.), leaving a brown residue in the flask. When the colorless odoriferous oil was redistilled the boiling point was found to be 80 to 84° C. The oil had an intense lumbang odor, and the yield was about 2 per cent.

When the oil was treated with a glacial acetic acid solution of benzidine a decided orange color was obtained, indicating the presence of aldehydes. The oil decolorized a solution of pale, yellow, dilute bromine water and also a dilute solution of alkaline potassium permanganate, indicating that the oil contained unsaturated compounds.

The refractive index was determined at 20° C., and found to be 1.3638.

The oil is soluble in ethyl alcohol, methyl alcohol, ether, acetone, benzyl alcohol, glycerol, amyl alcohol, ethyl acetate, glacial acetic acid, and propyl and isopropyl alcohols. When treated with water it forms a turbid solution, but further addition of water gives a clear solution. It is insoluble in chloroform, benzene, xylene, nitrobenzene, toluene, carbon tetrachloride, and gasoline.

Mixed acids.—The zinc salts, prepared as described above, were treated with hot ethyl alcohol (95 per cent). A small quantity of a heavy oil separated out at the bottom of the alcoholic solution. The oil, when separated from the supernatant alcoholic solution and cooled, changed to a white solid. Investigation showed that this material consisted largely of oxidized zinc salts.

The alcoholic solution of unoxidized zinc salts was allowed to crystallize. The zinc salts were dried first on layers of filter paper and later in a vacuum desiccator. The weight of the zinc salts was ascertained, and they were then placed in a round flask which was fitted with a stopper containing three holes. In one hole was placed a tube which served to introduce carbon dioxide into the flask. A dropping funnel was passed through the middle hole, and through the third hole was passed a tube connected to a Bunsen safety valve. About 150 cubic centimeters of water were then poured into the flask through the dropping funnel. Carbon dioxide gas was generated by treating marble with dilute hydrochloric acid (1:3). The gas was purified by passing through two wash bottles containing sodium carbonate solution (which removed the hydrochloric acid vapors), and dried by passing through a wash bottle containing concentrated sulphuric acid and two bottles containing calcium chloride. The purified carbon dioxide was passed into the flask containing the mixed lumbang zinc soaps. The flask was then placed in a boiling-water bath and after the soaps had melted somewhat a dilute sulphuric acid solution (1:3) was introduced at intervals into the flask through the dropping funnel. After each addition of sulphuric acid the flask was shaken thoroughly. The zinc salts were thus gradually converted into the free mixed acids in an atmosphere of carbon dioxide. The mixture was cooled to room temperature. The mixed acids were then extracted with ether, and the ether extract was washed several times with distilled water and the

extract was then dehydrated with sodium sulphate and filtered. The weight of mixed acids contained in the ether solution was calculated from the known weight of zinc salts used.

Linolenic hexabromide.—The ethereal solution of mixed acids was diluted with a sufficient amount of ether to make the concentration one part of mixed acids to eight parts of ether. The diluted ethereal solution of mixed acids was treated with a slight excess of the calculated amount of bromine, according to the procedure used by Imperial and West.⁵ The ether solution of mixed acids was stirred mechanically by means of a hot-air motor and brominated at -10° C. The insoluble linolenic hexabromide was removed by filtering. After crystallizing from ethyl acetate and benzene, the melting point of the hexabromide was 179.5 to 180.5° C.

Analysis of the linolenic hexabromide gave the following results:

	Bromine.
Calculated for $C_{18}H_{30}O_2Br_6$	Per cent.
Found	63.32
	63.02

Alpha linolic tetrabromide.—The ethereal filtrate from the hexabromide was treated with sodium thiosulphate solution, to remove the bromine, and was then separated, dehydrated with anhydrous sodium sulphate, and filtered. The solution was then distilled to eliminate the ether. In order to facilitate the removal of the last portion of ether the mixture was distilled on a water bath (60° C.) and a current of carbon dioxide passed into the distilling flask. The residue was treated with cold petroleum ether which precipitated a mixture of linolic tetrabromides. The mixed tetrabromides were washed with petroleum ether, which removed principally the liquid oleic dibromide and also some liquid tetrabromide. The crude crystalline product was then dried on layers of filter paper. The tetrabromide crystals were somewhat yellow and they were also rather sticky and gummy, due to the fact that they were saturated with oils which were somewhat insoluble in petroleum ether. After crystallizing from ethyl alcohol the melting point was 110 to 113° C. The alcoholic filtrate from the crystallized tetrabromide was distilled until about a quarter of the alcohol

⁵ Philip. Journ. Sci. 31 (1926) 441-449.

was removed. When the remainder of the solution was cooled a second crop of tetrabromide (melting point, 110 to 113° C.) was obtained. The filtrate from the second crop of crude tetrabromide was set aside for further investigation.

The combined yields of tetrabromide were washed again with petroleum ether and crystallized once from gasoline and several times from ethyl alcohol. After this further purification the melting point was 112.3 to 114.3° C.

Analysis of alpha linolic tetrabromide showed the following results:

	Bromine.
Calculated for $C_{18}H_{32}O_2Br_4$	Per cent.
Found	53.33
	53.73

This substance which, in accordance with the nomenclature adopted by Takahashi, we called alpha linolic tetrabromide, was the same as the tetrabromide prepared by West and Montes.⁶

Gamma linolic tetrabromide.—When the alcoholic filtrate from the second crop of alpha tetrabromide was concentrated, by distilling off about a third of the remaining alcohol, a red oily layer separated out at the bottom of the alcoholic solution. The red oil was then separated from the supernatant alcoholic solution of the alpha compound. When the red oil was shaken with a small quantity of cold ethyl alcohol a considerable portion of it gradually crystallized and was converted into silky crystals. The crystallization can be hastened somewhat by cooling the mixture in ice water.

That portion of the red oil which did not crystallize was analyzed and gave the following results:

Analysis of gamma linolic tetrabromide (red oil filtrate from silky crystals).

	Bromine.
Calculated for $C_{18}H_{32}O_2Br_4$	Per cent.
Found	53.33
	53.37

According to the analysis, this red oil would thus appear to be a liquid tetrabromide and may, perhaps, be identical with the liquid tetrabromide (gamma linolic tetrabromide) described by Takahashi.⁷ Our liquid tetrabromide we called gamma linolic tetrabromide.

⁶ Philip. Journ. Sci. 18 (1921) 619.

⁷ Journ. Tokyo Chem. Soc. 40 (1919) 233.

Silky crystals (mixture of two substances).—The silky crystals obtained from a portion of the red oil were washed several times with cold ethyl alcohol. They melted at 59.6 to 60.6° C.

Analysis of the silky crystals gave the following results:

	Bromine.
Calculated for $C_{18}H_{32}O_2Br_4$	Per cent.
Found	53.33
	53.32

These silky crystals appeared to be a low-melting tetrabromide. The crystals were soluble in cold ether, chloroform, benzene, xylene, acetone, benzyl alcohol, nitrobenzene, toluene, carbon tetrachloride, gasoline, ethyl acetate, glacial acetic acid, and petroleum ether.

When the silky crystals were treated with warm methyl alcohol, a colorless oil separated out at the bottom of the alcoholic solution. The colorless oil was separated from the supernatant alcoholic solution and, when cooled, it changed to an amorphous white solid. The alcoholic solution when cooled with ice water gave a considerable quantity of white crystals. This behavior of the silky crystals indicated that they were a mixture of two substances, one of which was more soluble in warm methyl alcohol than the other. The silky crystals consisted of approximately 75 per cent of the very soluble substance which crystallized from the methyl alcohol solution and 25 per cent of the amorphous white solid that was not so readily soluble in methyl alcohol. Weighed quantities of each of these substances were treated with a sufficient amount of cold methyl alcohol to dissolve each of them. When calculated on the basis of 100 cubic centimeters of solvent, the results showed that 100 cubic centimeters of cold methyl alcohol, at room temperature (27° C.) dissolved 0.7463 gram of the crystallized substance and only 0.2164 gram of the amorphous substance.

Beta linolic tetrabromide.—The crystallized substance which was readily soluble in warm methyl alcohol was crystallized from the methyl alcohol solution. The melting point was 59 to 60° C. When observed under the microscope the crystals appeared as bundles of rods. We called this substance the beta linolic tetrabromide.

Analysis of beta linolic tetrabromide.

	Bromine.
Calculated for $C_{18}H_{32}O_2Br_4$	Per cent.
Found	53.33
	53.44

This beta linolic tetrabromide may be identical with the beta linolic tetrabromide (melting point 59 to 60° C.) obtained by Takahashi⁸ from soy-bean oil.

Delta linolic tetrabromide.—That portion of the silky crystals which was not so readily soluble in methyl alcohol (the colorless oil that changed to a white solid) gave a melting point of 57 to 58° C. When crystallized from ethyl alcohol and viewed under the microscope the crystals appeared as bundles of needles. We called this substance delta linolic tetrabromide.

Analysis of delta linolic tetrabromide.

Calculated for $C_{18}H_{32}O_2Br_4$	Bromine. Per cent.
Found	53.33 53.28

This delta linolic tetrabromide may be the same as the tetrabromide crystals (melting point, 57 to 58° C.) obtained by Matthes and Boltze⁹ from the oil of wallflower seeds.

Our experiments would seem to indicate that we had prepared from lumbang oil not only linolenic hexabromide, oleic dibromide, and an odoriferous oil, but also four different linolic tetrabromides. Data on the tetrabromides are summarized in Table 1.

TABLE 1.—*Linolic tetrabromides from lumbang oil.*

Name.	Melting point.	Bromine content. *	Solubility in 100 cubic centimeters of cold methyl alcohol at 27° C.	Crystal form.
	°C.	Per cent.	g.	
Alpha	112.3–114.3	53.73	Not determined.	Not determined.
Beta	59 – 60	53.44	0.7463	Rods in bundles.
Delta	57 – 58	53.28	0.2164	Needles in bundles.
Gamma	Liquid.	53.37	Not determined.	Liquid.

* Bromine content calculated for $C_{18}H_{32}O_2Br_4$ (linolic tetrabromide) is 53.33 per cent. The temperatures recorded were corrected.

The tetrabromide silky crystals which were a mixture consisting of about 75 per cent of the beta compound and 25 per cent of the delta compound gave a melting point of 59.6 to 60.6° C. This is somewhat higher than the melting point of the delta compound, which is only 57 to 58° C. Beta and delta linolic tetrabromides were mixed in the proportion of 75 per cent of the beta and 25 per cent of the delta. The melting point of this mixture was found to be 59 to 60° C., which is identical with the melting point of the beta compound and approximately

⁸ Journ. Tokyo Chem. Soc. 40 (1919) 233.

⁹ Archiv der Pharmazie 250 (1912) 225.

the same as the melting point of the silky crystals prepared from lumbang oil.

Takahashi¹⁰ prepared alpha linolic tetrabromide (melting point, 114° C.) and reduced it to the free linolic acid which was again brominated. He thus obtained three isomeric tetrabromides. From his work it would appear that the elimination and, perhaps, the readdition of bromine gave molecular rearrangements which produced isomeric tetrabromides.

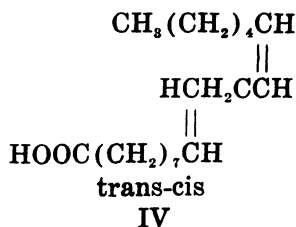
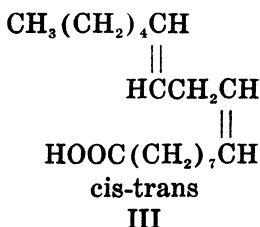
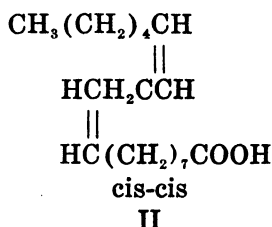
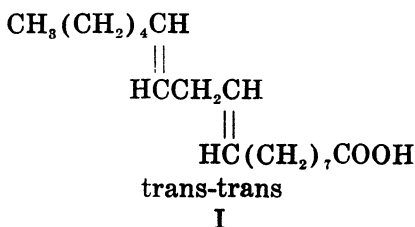
In our experiments with lumbang oil, the four isomeric tetrabromides were prepared by brominating directly the mixed acids which occur as glycerides in lumbang oil. There was no reduction of tetrabromides and rebromination of linolic acids.

Linolic acids.—From our results it would appear that lumbang oil may contain, perhaps, four different linolic glycerides. When these mixed glycerides are converted into the free linolic acids and brominated, each acid yields a particular tetrabromide which is different from the other tetrabromides.

If the formula¹¹



is accepted as the correct formula of linolic acid, then four space isomers of such a substance are possible. The formulas of these four isomeric linolic acids can be represented as follows:



¹⁰ Journ. Tokyo Chem. Soc. 40 (1919) 233.

¹¹ Beilsteins Handbuch der Organischen Chemie, Vierte Auflage, 2 (1920) 496.

From the results of their experiments on cottonseed oil, Nicolet and Cox¹² were inclined to think that the trans-trans and trans-cis linolic acids were the only linolic acids occurring naturally as glycerides in cottonseed oil.

DISCUSSION OF RESULTS

Our results seem to indicate that, perhaps, lumbang oil contains all four linolic acids which are present as glycerides in the oil. If this be so, then, when the glycerides of lumbang oil are converted into mixed acids and these acids brominated, we should obtain linolenic hexabromide, four linolic tetrabromides (alpha, beta, delta, and gamma), and oleic dibromide. It appears that we have prepared all of these substances in this investigation. In making these compounds the insoluble hexabromide is first removed by filtering. After eliminating the ether solvent, the tetrabromides are precipitated with petroleum ether and removed by filtering. The petroleum ether filtrate from the crystallized tetrabromides consists principally of liquid linolic tetrabromide (gamma) and oleic dibromide, as shown by West and Montes.¹³ We found that, when this filtrate was allowed to stand a few weeks, some crude crystals separated out. Investigation showed that these mixed crystals consisted largely of beta and delta tetrabromides and, also, a small quantity of the alpha compound.

As previously stated, the crude alpha linolic tetrabromide, when first precipitated and washed with petroleum ether, appeared to be saturated with heavy oils. When this tetrabromide was crystallized from ethyl alcohol, and the filtrate from the second crop of crystals concentrated, a red oil separated out. When this red oil was removed and treated with ethyl alcohol, a considerable portion of it was gradually converted into silky crystals, which consisted of a mixture of two crystallized tetrabromides (beta and delta). These tetrabromides can be separated by treating them with methyl alcohol, which dissolves the beta compound more readily than the delta compound.

We thought that, possibly, the silky crystals were formed from the alpha tetrabromide by a molecular rearrangement and the red oil which separated out was a transition stage in the transformation of the alpha into the beta and delta compounds.

¹² Journ. Am. Chem. Soc. 44 (1922) 144.

¹³ Philip. Journ. Sci. 18 (1921) 619.

In order to test this point, we dissolved some of our purest alpha tetrabromide in ethyl alcohol. The solution was allowed to crystallize. The filtrate from the second crop was concentrated, but no red oil separated out. The red oil is obtained only by concentrating the alcoholic filtrate from the precipitated crude alpha compound prepared directly from lumbang oil.

Our results would seem to indicate that, when the mixed tetrabromides are first precipitated with petroleum ether, the beta and delta compounds are obtained as heavy oils which adhere tenaciously to the crystallized alpha compound. There is also a small amount of the oily gamma compound in the mixture as well as some oleic dibromide. The mixed bromides are washed with petroleum ether to eliminate the oily oleic dibromide and also some liquid tetrabromide, and then they are crystallized from ethyl alcohol. The filtrate from the second crop of the crystallized alpha compound is a dilute alcoholic solution of the alpha, beta, delta, and gamma compounds. By concentrating this filtrate, the beta, delta, and gamma compounds separate out as oils, because these substances are insoluble in a concentrated alcoholic solution of the alpha compound. When these oils are separated from the supernatant alcoholic solution of the alpha compound, the beta and delta compounds are gradually changed to silky crystals. The addition of some alcohol at this stage facilitates the crystallization, because the alcohol tends to dissolve the small quantity of gamma compound which is present.

In order to test our idea as to how the beta and delta compounds were obtained, we dissolved small portions of the individual purified alpha, beta, delta, and gamma compounds in ethyl alcohol. When the alcoholic solution of these four compounds was concentrated and cooled the red oil separated out as usual. When the red oil was separated from the supernatant alcoholic solution of the alpha compound and treated with a small quantity of ethyl alcohol, a considerable portion of the oil was gradually converted into silky crystals.

The beta and delta compounds appear to be new substances, which have not been definitely described in the literature.

SUMMARY

Lumbang oil consists principally of a mixture of unsaturated glycerides (linolenic, linolic, and oleic). It also contains an odoriferous oil which has an intense lumbang odor and boils at 80 to 84° C.

The odoriferous oil is soluble in water and various organic solvents, and gives positive tests for aldehydes and unsaturated compounds.

In addition to linolenic hexabromide and oleic dibromide, four isomeric linolic tetrabromides may be obtained from lumbang oil. They are as follows:

Linolic tetrabromide.	Melting point. °C.
Alpha	112.3-114.3
Beta	59-60
Delta	57-58
Gamma	Liquid.

By concentrating the alcoholic filtrate from the alpha compound, a red oil is obtained. When isolated, a considerable portion of this red oil is gradually converted into silky crystals. These crystals consist of a mixture of beta and delta compounds, which may be separated by means of methyl alcohol. It appears that the individual beta and delta compounds have not been definitely described in the literature.

These four linolic tetrabromides may have been obtained, perhaps, from four different linolic acids which were present as glycerides in the lumbang oil.

ACKNOWLEDGMENT

We wish to express our thanks and appreciation to Mr. Frederick L. Smith, 2d, chief chemist, Quartermaster Corps, United States Army, Manila, who kindly made our bromine analyses for us.

TINGITIDÆ FROM THE FAR EAST (HEMIPTERA)

By CARL J. DRAKE

Of Iowa State College, Ames

Through the courtesy of C. F. Baker, dean of the College of Agriculture, University of the Philippines, and of other co-workers I have received for study collections of lace bugs from India, China, Japan, and the Philippine Islands. In classifying these collections two new genera and eight new species have been discovered, which are characterized herein.

MONANTHIA EVIDENS sp. nov.

Very similar to *M. formosa* Drake, but slender, much darker in color, the pronotum more evenly rounded on the sides, and the nervure between subcostal and discoidal areas at the apex of discoidal area (over tumid elevation) rounded and not angulate.

Antennæ testaceous, the basal half of the first segment slightly embrowned, the proportional lengths of the segments as in *M. formosa*. Rostrum reaching between the intermediate coxæ. Venter with two prominent, black, stout, blunt, obliquely projecting tubercles, one on each side of the penultimate segment. Head black; the posterior spines brownish, contiguous with the surface of the head, reaching to near the anterior margin of the eyes; median and anterior spines greatly reduced, represented by very short, blunt, black tubercles. Pronotum and paranota black, the cells a little lighter, the lateral carina, if present, represented by short, black, oblique nervures. Legs testaceous.

Elytra black, the areolæ mostly whitish but some of them partly embrowned; costal area narrower than in *M. formosa*, the transverse nervures on basal half black; subcostal area broad, triseriate; discoidal area with five areolæ at its widest part, the nervure between discoidal and costal areas curved, rounded at the tumid elevation.

Length, 2.7 millimeters; width, 1.02.

Holotype, female, Imugan, Nueva Vizcaya, Luzon (*Baker*), in Drake collection. Specimens of both *M. sauteri* Drake and *M. formosa* Drake are at hand from the Philippine Islands, here-

tofore recorded only from Formosa. *Monanthia evidens* is closely allied to *M. formosa*, but easily separated from it by the tubercles on the venter (projecting obliquely outward), the paranota, and the shape of the nervure between subcostal and discoidal areas at the apex of the latter.

ONCOPHYSA CONSTANTIS sp. nov.

Moderately elongate, stout, brown, with testaceous and fuscous markings. Head black; spines testaceous, blunt, stout, moderately long; posterior spines directed forward, touching the surface of the head, reaching to the anterior spines; median and anterior spines pointed slightly downward, the anterior pair with their tips almost touching. Rostral laminae very widely separated on the metasternum, the rostrum reaching to the mesometasternal suture.

Antennae long, brown; segment I stouter and nearly twice as long as the second; III long, slender; IV wanting. Pronotum tricarinate, strongly tumid through the disk; paranota formed as in *O. vesiculata* Stål, but more tumid, a little higher, not shiny, and the nervures more prominent.

Elytra testaceous brown, rather dull, with a number of fuscous cells in the sutural areas; costal area composed of one row of moderately large cells, with a dark band (two or three cells) at its widest part; discoidal area large, the outer margin slightly curved, areolae strong depressed; subcostal area biserrate, the areolae slightly smaller than those of discoidal area. Wings a little shorter than the elytra. Length, 4.24 millimeters; width, 1.16.

Holotype, female, Hongkong, China (*H. Koebele*), in Drake collection. This species may be separated from *O. vesiculosa* Stål by its shorter antennae, larger paranota, rather dull dorsal surface of the body, and costal area.

DIPLOCYSTA NIMIA sp. nov.

Elongate-ovate, broad, large, brown, with blackish markings. Head short, broad; median and anterior spines very short, blunt, posterior spines short, rather slender, touching the surface of the head, not reaching anterior spines. Bucculae closed in front. Antenniferous tubercles large, very broad, prominent.

Antennae long, rather slender, brown, the fourth segment (except a very small basal portion) black; segment I considerably larger and longer than the second; II very short, not very stout, less than half as long as I; III slender, slightly more than twice

the length of IV. Pronotum tricarinate, the entire dorsal surface above, except small median portion of collum and posterior triangular portion, concealed by the enormously developed and inflated paranota; median portion of triangular process raised, rooflike, the median carina placed on this rooflike ridge; lateral carinæ, except small apical portion, concealed by the paranota. Paranota enormously developed, strongly tumid, a little longer than broad, crests widely separated (deep V-shaped space between them); areolæ large, opaque, dull, a little lighter in color than the nervures; nervures brown, shiny.

Elytra very broad, rounded at the apex, broadest at the apex of pronotum (triangular process), testaceous brown, with fuscous or black markings, the apical portion fuscous; costal area broad, with outer margin somewhat curved, the areolæ moderately large, not arranged in regular rows, with a very broad, blackish fascia at widest portion; subcostal area broad, composed of five rows of small areolæ, with a long, prominent, costate nervure near the outer margin (separating one row of cells along the costal margin), composed of six rows of cells; discoidal area large, broad, strongly impressed, bounded by a prominent nervure, outer margin nearly straight, composed of nine or ten cells at its widest part. Length, 5.12 millimeters; width, 2.34.

Holotype, male, Cuernos Mountains, Negros (*Baker*), in Drake collection.

DIPLOCYSTA NUBILA sp. nov.

Form, size, and general appearance very much like *D. nimia* sp. nov., but distinguished from it by its dark, fuscous or blackish, narrowly separated paranota, the nonelevated median portion of the triangular process of the pronotum, and the narrower costal area of the elytra.

Antennæ long, segments I and II slightly shorter than in *D. nimia*. Paranota enormously developed, blackish fuscous, the great tumid structures deeply and narrowly separated, the crests not widely separated. Bucculæ closed in front.

Elytra a little narrower than in *D. nimia*, not so strongly marked with fuscous or black; costal area moderately broad, with three to four rows of areolæ, the areolæ more regularly arranged, with a narrower brown fascia near the middle; subcostal area with slightly larger areolæ, the row of cells between the costate nervure of subcostal area and costal area a little

larger; discoidal area distinctly impressed, composed of eight or nine cells at its widest part; sutural area much lighter than in *D. nimia*. Length, 4.7 millimeters; width, 2.04.

Holotype, female, Singapore (*Baker*), in Drake collection. This peculiar insect is a little smaller than and very distinct from *D. nimia* sp. nov.

Genus UHLERITES novum

Distinctly lacy, elongate, obovate. Head very short, with five spines, the posterior pair contiguous with surface of head. Buculae closed in front.

Antennae long, slender; segment I stouter and longer than II; segment III very long and slender; segment IV longer than I, slightly enlarged toward the tip. Orifice prominent. Rostral channel uninterrupted. Pronotum strongly and transversely swollen through the disk; coarsely punctate, strongly narrowed anteriorly, unicarinate; humeri prominent. Hood moderately large, subangularly projecting over base of head. Paranota reticulate, moderately broad, angularly projecting in front.

Elytra reaching considerably beyond the apex of abdomen; costal and subcostal areas broad; discoidal area about reaching the middle of the elytra, the boundary between discoidal and subcostal areas distinctly raised.

Type of genus, *Uhlerites* (*Phyllontocheila*) *debile* Uhler, from Japan.

This genus is closely allied to *Gelchossa* Kirkaldy, from which it can be separated by the unicarinate pronotum, very short head, thicker nervures, and differently formed paranota and hood.

HORMISDAS VICARIUS sp. nov.

Coloration, form, and size very similar to *H. pictus* Distant. Hairs fine, slightly curled. Paranota moderately reflexed, biseriate, the outer margins nearly straight and not roundly emarginate on the sides in front, as in *H. pictus*, each armed with a long spine in front. Carinae slightly more raised than in *H. pictus*, the median carina more raised in front and the dorsal margin nearly straight. Spines on the head long, sharp, slenderer than in *H. pictus*. Costal area of elytra moderately broad, irregularly biseriate, a little narrower than in *H. pictus*, the nervure between subcostal and discoidal areas (near the middle), and the apex of discoidal area only slightly raised. Length, 2.9 millimeters; width, 1.2.

Four specimens. Holotype, male, Larat (*Muir*) in my collection. Paratypes, one, Larat (*Muir*); two, Los Baños, Philippines (*Baker*). In Baker and Drake collections.

The above description is made from comparison with a male cotype of *H. pictus* Distant.

Genus XENOTINGIS Drake (1923)

Xenotingis DRAKE, Ohio Journ. Sci. 23 (1923) 105.

Orthotype, *Xenotingis horni* Drake.

This genus is based upon a single species, *X. horni* Drake, from Formosa. A second species, described from a single specimen, slightly modifies the original description of the genus. The pronotum is uni- or tricarinate; the posterior triangular process is more or less produced. The areas of the elytra are not differentiated in the new species described below.

Key to species of *Xenotingis* Drake.

- Pronotum tricarinate, the triangular portion long and visible behind the enormously developed paranota; margins of paranota forming a large round opening above the pronotum..... *X. horni* Drake.
 Pronotum unicarinate, the triangular portion short and not quite reaching to the center of the paranota; margins of paranota forming a narrow opening above the pronotum..... *X. bakeri* sp. nov.

XENOTINGIS BAKERI sp. nov.

Narrow, elongate, testaceous, the pronotum enormously developed. Head short, testaceous, with five spines; posterior spines moderately long, blunt, directed forward, contiguous with the dorsal surface of the head; anterior spine not very long, appressed; anterolateral spines moderately long, semierect, their tips touching. Rostral channel widening posteriorly, the rostrum extending to the end of rostral channel. Bucculæ closed in front.

Antennæ long, slender, somewhat curved, the apical segment clothed with a few rather short hairs; segment I a little longer and stouter than II; III long, very slender, nearly four times the length of IV. Pronotum unicarinate, very much concealed by the extremely large paranota; posterior process very short, the apex bluntly rounded. Paranota enormously developed, somewhat globose, projected high above the pronotum and base of elytra, a little longer than high, the outer margins not widely separated above the pronotum; areolæ large, clouded with pale brown; apex of triangular process of pronotum not quite reaching to the middle of the paranota. Hood moderately large,

projecting a little over the base of the head, the median carina slightly raised anteriorly.

Elytra considerably longer than the abdomen, rounded at the apex, the outer margins (on each side) recurved; areas not differentiated, the areolæ rather large. Wings much shorter than the elytra but longer than the abdomen. Length, 3.15 millimeters; width, 0.8.

Described from a male specimen (holotype), Los Baños, Philippines (*Baker*), in my collection. This species is very distinct from *X. horni* Drake from Formosa.

XENOTINGIS HORNI Drake.

Xenotingis horni DRAKE, Ohio Journ. Sci. 23 (1923) 105, fig. 1.

This species was described from a female specimen from Kosempo, Formosa, collected by Mr. H. Sauter. It can be easily distinguished from *X. bakeri* by the characters of the paranota and pronotum.

Genus ALLOIOTHUCHA novum

Distinctly lacy, as in the genera *Stephanitis* Stål, *Gargaphia* Stål, *Leptobrysa* Stål, and *Corythucha* Stål. Rostral channel uninterrupted. Antennæ long, slender; segment III slenderest, only slightly longer than IV; segment IV very long. Bucculæ not contiguous in front. Intermediate and posterior coxæ widely separated. Head short, concealed from above by hood. The spines reduced. Pronotum and head entirely concealed by an enormous cyst, the reticulations rather large. Paranota narrow, areolate. Elytra widely reticulated, extending considerably beyond the apex of the abdomen, the tips rounded and widely separated; discoidal area not reaching the middle of the elytra.

The extremely large and strongly inflated cyst (covering the head, pronotum, paranota, and posterior process of pronotum) separates this genus from closely related genera.

Type of genus, *Alloiothucha philippinensis* sp. nov.

ALLOIOTHUCHA PHILIPPINENSIS sp. nov.

Testaceous, the enormous cyst embrowned, the cells of elytra hyaline. Head short, concealed by the hood. Rostrum reaching to the end of the rostral channel.

Antennæ slender, long, testaceous; segment I a little longer and slightly stouter than II; segment III only slightly longer than IV (III=38; IV=34); segment IV slightly swollen, clothed with a few short hairs. Pronotum entirely concealed by the

extremely large hood. Paranota narrow, biseriate, reflected almost vertically, the areolæ small. Body beneath brownish. Hood enormously developed, strongly inflated, ellipsoidal, a little longer than high; areolæ large, embrowned, nontransparent.

Elytra divaricating posteriorly, rather widely reticulated; costal area broad, with three rows of cells at its widest part, the areolæ of costal and discoidal area subequal in size; subcostal area uniseriate, the cells very small along the discoidal area; discoidal area short, widening posteriorly, not reaching the middle of the elytra, angulate behind, with four rows of cells at its widest part, the areolæ only slightly smaller than those of sutural area. Wings atrophied. Legs yellowish brown. Length, 3.1 millimeters; width, 2.

Holotype, male, Mount Maquilang, Luzon (*Baker*), in my collection.

ALLOIOTHUCHA NECOPINATA sp. nov.

Closely related to *A. philippinensis* sp. nov., but readily separated from it by the much shorter paranota and the wider costal area of the elytra. Length, 3 millimeters; width, 2.

Antennæ slightly stouter than in *A. philippinensis*; segment III distinctly longer than IV (III=44; IV=35). Paranota short, biseriate, not reaching to the posterior margin of humeri, the outer margin rounded. Hood ellipsoidal, a little longer than in *A. philippinensis*; areolæ smaller, embrowned, nontransparent. Rostrum long, reaching to the apex of rostral channel.

Elytra divaricating posteriorly, not as broadly rounded at the apex as in *A. philippinensis*; costal area broad, with four or five rows of cells at its widest part; discoidal area not reaching the middle of the elytra, rounded behind, with four rows of cells at its widest part; subcostal area uniseriate. Wings almost as long as the abdomen. Body beneath dark reddish brown.

Holotype, male, Puerto Princesa, Palawan (*Baker*), in my collection.

Key to species of Alloiothucha g. nov.

Costal area of elytra triseriate at its widest part; the discoidal area angulate behind; paranota extending to the base of elytra.

A. philippinensis sp. nov.

Costal area with four or five rows of areolæ at its widest part, the apical margin of discoidal area rounded; paranota short, not reaching to the base of elytra..... *A. necopinata* sp. nov.

ZWEI NEUE ANOMALA-ARTEN DER PHILIPPINEN (COLEOPTERA, LAMELLICORNIA, RUTELIDEN)

Von F. OHAUS

Mainz, Germany

EINE TEXTFIGUR

ANOMALA FUSCAOAEREA sp. nov.

Diese Art bildet einen Uebergang zwischen der *A. camariensis* Ohaus und *inconsueta* Ohaus. Gestreckt eiförmig, hinten leicht verbreitert, flach gewölbt. Kopf, Vorderrücken, Schildchen, die Unterseite und die Schienen nebst Tarsen sind dunkelbraun mit kupfrigem Bronzeschimmer, wenig glänzend, die Deckflügel, Afterdecke und die Schenkel hellbraun, die letzteren allein mit schwachen grünen und kupfrigen Lichtern. Oberseite kahl, die Spitze der Afterdecke und die Brust nebst Hüften mit spärlichen kurzen gelben Haaren. Kopfschild, Vorderrücken, und Schildchen sind dicht, vielfach zusammenfliessend und ziemlich grob punktirt, die basale Randfurche in der Mitte unterbrochen. Auf den Deckflügeln ist von der primitiven Sculptur nur noch die die Nahtrippe begrenzende primäre Punktreihe und von den primären Rippen kurze Reste der II. III. IV. und V. neben dem Spitzenbuckel erhalten; sonst sind die Deckflügel dicht bedeckt mit zusammenfliessenden grossen Ringpunkten, zwischen denen kurze Querrunzeln verlaufen, die ganze Oberfläche überstreut mit sehr feinen Pünktchen, zumal auf der Nahtrippe. Afterdecke mit grossen Ringpunkten und groben Querrunzeln, Unterseite (Bauch, Brust, und Hüften) mit einzelnen grossen Ringpunkten, die nur an den Seiten zusammenfliessen. Vorderschienen mit grossem löffelartigem Spitzenzahn und einem scharfen Seitenzahn; Mittel- und Hinterschienen mit je zwei schiefen Borstenreihen. Fühler hellbraun.

Länge, 21 Millimeter; Breite, 11.

Weib, von Samar (*C. F. Baker*).

EUCHLORA HORTENSIA sp. nov.

Der *E. latefemorata* Ohaus von Nord-Borneo zünächst verwandt. Gestreckt eiförmig, hinten leicht verbreitert. Ober-

seite und Afterdecke satt grasgrün, glänzend; Unterseite, Schienen, und Füsse erzgrün, alle Hüften und Schenkel braungelb mit lebhaftem rotem Kupferschiller; Fühler hellbraun. Kopf, Schildchen, und Vorderrücken fein einzeln punktirt, die Seiten des letzteren schmal gelb gesäumt und die basale Randfurche

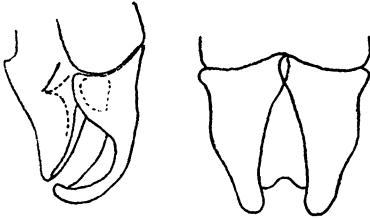


FIG. 1. *Euchlora hortensia* sp. nov.;
Forceps, dorsale und linke Seitenansicht.

in der Mitte unterbrochen. Die Deckflügel weitläufig fein punktirt mit regelmässigen primären Punktreihen, deren Punkte etwas grösser als die zerstreuten Pünktchen sind. Afterdecke kahl, sehr dicht und fein rissig punktirt, fast matt. Bauchringe lebhaft glänzend, mit der

gewöhnlichen Querreihe von Borstenpunkten; Hüften und Brust kurz gelb behaart. Beine ohne Besonderheiten. Am Forceps, Fig. 1, sind die Parameren symmetrisch, frei, nicht so stark verschmälert als bei der *latefemorata*, die Ventralplatte des Mittelstückes in ihrer apicalen Hälfte schaufelförmig, ihr Vorderrand schwach ausgeschnitten.

Länge, 21 Millimeter; Breite, 11.5.

Mann, Samar (*Baker*).

ILLUSTRATION

TEXTFIGUR

FIG. 1. *Euchlora hortensia* sp. nov.; Forceps, dorsale und linke Seitenansicht.

IMPERFECT HERMAPHRODITISM IN FLOWERS OF HIBISCUS, REMOVED BY SURGICAL OPERATION ¹

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FOUR PLATES

INTRODUCTION

In the course of my genetic studies on *Hibiscus*, there were discovered in this genus various degrees of sterility and fertility which seem to me of biologic interest. One of the sterile forms was found in the flowers of a certain variety of *H. rosa-sinensis*. The species is supposed to bear hermaphroditic buds and flowers; but in the case of the variety the stigmas, as a rule, owing to abnormal shortness of style, fail to reach even the terminal column when the flower is in bloom. We have here, then, a case of imperfect hermaphroditism. I do not know the origin of this variety; I am sure it is not one of our seedlings. Since Wilcox and Holt ² reported in 1913 that they obtained in Hawaii a hybrid with this peculiarity, and as many of our introduced varieties were imported from Hawaii, it is possible that the variety under discussion is identical with that of Wilcox and Holt. It will be of horticultural interest to ascertain if this is a case of a perfect hermaphrodite under foreign conditions becoming imperfect upon a change of environment. Until the identity of the variety under report is known, I am giving it the convenient variety name of Prisoner. It may be remarked that this variety is odorous. The case of protandrous sterility just described also occurs, though very rarely, in three other, quite distinct varieties in my collection; namely, the Woodrow Wilson, which is also odor-producing; the Two-Days, the flower of which, unlike those of other varieties, blooms for two days; and the Jamaica. A highly significant peculiarity of the Prisoner is that a plant of this variety, budded on a Native Red Single stock about 10 years

¹ Read before the Los Baños Biological Club, December 11, 1924.

² Ornamental Hibiscus in Hawaii, Bull. Hawaii Agr. Exp. Sta. 29 (1913).

old, produces mostly perfect hermaphrodites. Table 1 is a record of the condition of the flowers produced by the Prisoner from November 26, 1924, to February 9, 1925.

TABLE 1.—Showing the variability in distance between the uppermost stigma and opening of staminal column in flowers of the same age of *Hibiscus rosa-sinensis* var. Prisoner, collected November 26, 1924, to February 9, 1925.

Class range.	In flowers of a plant budded on another variety.	In flowers of plants growing on their own roots.
	Flowers.	Flowers.
Twelve to 17 millimeters above opening.....	3	0
Six to 11 above opening.....	54	4
Less than 6 above opening.....	36	14
At opening.....	1	11
Less than 6 millimeters below opening.....	2	52
Six to 11 below opening.....	3	15
Twelve to 17 below opening.....	0	1
Eighteen to 23 below opening.....	0	0
Twenty-four to 29 below opening.....	0	0
Thirty to 35 below opening.....	1	0
Thirty-six to 41 below opening.....		0
Forty-two to 47 below opening.....		1
Forty-eight to 53 below opening.....		1
No style *.....		1
Total.....	100	100

* The length of the normal style of the variety is about 100 millimeters.

Table 1 shows the variability in distance between the uppermost stigma and the opening of the staminal column. It will be observed that, typically, the flower of Prisoner on a budded plant has its uppermost stigma about 6 to 11 millimeters above the opening. Ninety-three per cent of the flowers had stigmas above the opening; in other words, ninety-three per cent of the flowers were in position to function in pollination. On the other hand, plants growing on their own roots produced typically flowers with stigmas only within 6 millimeters of the opening of the staminal column. Seventy-two per cent of the flowers of such plants produced their stigmas below the opening of the column and were not in position to function in pollination.

It would appear that there is a tendency for Prisoner of both sexes growing on its own roots to be sterile; for, aside from the anatomical imperfection of its stigmas, its pollen is also physiologically incompatible with the stigmas of all the

fifteen varieties which I have pollinated with it and of five additional varieties pollinated by Mr. Unite, graduate assistant in plant breeding. Moreover, Prisoner is itself self-incompatible; that is, under conditions when it is female-fertile with other varieties, it is female-sterile with its own pollen.

It is to be noted again that the pollen from a budded plant of Prisoner was found fertile, or functional, with varieties on which pollen of the same variety but from plants growing on their own roots failed to function. For example: Variety Pink-10 was pollinated on November 6, 12, and 18, and December 5 and 9 with pollen from plants growing on their own roots, but none of the treated flowers produced fruit. The same variety, pollinated on December 4, 1924, with pollen from a budded Prisoner plant, produced a fruit which was harvested on January 9, 1925, and was found to contain three good seeds. Similarly, varieties Pink-14, Almost White, and Dwarf Pink were sterile to pollen from Prisoner plants growing on their roots, but fertile to pollen from a plant of the same variety budded on Native Red Single. The seeds obtained in these crosses were sown and found to be viable.

While the phenomenon of sterility may be profoundly concerned with theories of evolution of species, this work was undertaken not so much to secure evidence contributive to these theories as to attempt to induce fertility in a variety which is ordinarily self- and female-cross-sterile, so that I might study genetically its unique odoriferous quality.

SURGICAL OPERATION TO CORRECT IMPERFECT HERMAPHRODITY

How the operation was discovered.—One morning Mr. Unite, my assistant, brought to me three flowers of Prisoner, the stigmas of which were more or less exposed and which were more normal in appearance than those found in the staminal tube. The top of the column in these flowers had been removed by some agent. As I am somewhat familiar with the injuries which insects inflict on the flowers and flower buds of *Hibiscus*, I suspected at once that we had stumbled on a case of a surgical operation accidentally performed by insects which made possible normal development of otherwise anatomically functionless stigmas. As some time must have elapsed since the insect attacks for the stigmas to reach the mature stage, I further suspected that the injury to the terminal portion of the staminal tube must have taken place many hours before the flowers opened. I then decided to perform the following artificial surgical opera-

tion on the Prisoner flowers about twenty-four hours before they opened.

The surgical operation.—Essentially, this operation consists in splitting with a needle the terminal portion of the staminal tube which imprisons the stigmas and bending the split parts outward so as to expose the stigmas. The operation must be performed with care, so as not to injure the stigmas and the style while freeing the stigmas from the thin membrane covering them. It has been found, provided the work is done about twenty-four hours before the flower opens, that this operation is invariably effective in causing the stigmas to reach maturity and to attain a receptive condition by the time the flower blooms. Performing the operation immediately before pollination brought only partial success.

That essentially the same result is attained through insect attacks as by operation has already been pointed out. At least five species of insects have been observed feeding on flowers and flower buds of *H. rosa-sinensis* and any one of them should be capable of accomplishing the operation even in what is apparently an accidental way. These species³ are *Phaneroptera furcifera* Stål, *Phenacoccus hirsutus* Green, *Nisotra gemella* Erichson, *Nisotra* sp., and *Cosmophila erosa* Hübner.

FERTILITY OF STIGMAS EXPOSED THROUGH OPERATION

Through artificial operation.—It remains to show that stigmas released and exposed through this operation are functional. Stigmas of this sort were hand-pollinated on different days, both in my cultures at home by myself, and by Mr. Unite in our cultures in the plant-breeding garden. Using Pink-10 as male parent, several ripe fertile pods were produced on the Prisoner, thus proving the fertility of the stigmas exposed through surgical operation. Seeds of these pods have been sown and seedlings of the cross produced.

Through insect operation.—Two flowers, the stigmas of which were found barely out of the opening of the staminal column, were one day hand-pollinated with pollen of variety Pink-10. This pollination was also successful. However, I have no way of satisfying myself whether the stigmas of these flowers were out as a result of normal development or as the result of insect attack on the tip of the column. When the pollination was done the stigmas had emerged from the top of the column.

³ Identified by the department of entomology, College of Agriculture.

Whatever the case may be, there is no reason known at present why stigmas exposed accidentally should not be as potent as those exposed artificially. If this point be granted, we may assign a new, although apparently at present accidental, rôle to insects; namely, that of serving as agents in fruit production while performing their injurious work on the flowers. Perhaps in the case of the variety Prisoner (its stigmas being impotent anyway) the insects that eat off the staminal column are not to be classed as enemies; for, while they mutilate and devour the flowers, they nevertheless perform work really essential to the species, that of making reproduction possible. Up to date, Prisoner has not produced fruits that are the result of insect pollination. Other varieties, as our Unknown-3, Unknown-4, Unknown-7 (Pink \times Araña) F_1 -4, (Pink \times Araña) F_1 -5 and (Hawaiian Salmon \times Native Red) F_1 , have become fruitful through this agency. Several reasons may be assigned for the failure, thus far, of Prisoner to produce fruits in the open. One of these is that we have used almost daily practically all the flowers of our plants of this variety. Another reason is that the papilionid, *Ornithoptera nephereus* Gray, which according to my observation is the most efficient insect agent of pollination of *Hibiscus*, does not seem to care to visit *Hibiscus* flowers that are odoriferous, as is the case with those of the variety Prisoner. I have of course, found Prisoner flowers with pollen-covered stigmas on several occasions; but in these cases the wind might have served as a pollinating agent, not by carrying the pollen, as we ordinarily assume it to do, but by agitating the branches and causing the twigs and flowers to rub against each other, thus causing both autogamous and geitonogamous pollinations. In such a case, the pollen could have been that of Prisoner itself. Many *Hibiscus* varieties also would be capable of autopollination when the stigmas have just emerged. It has been pointed out that the pollen of Prisoner is impotent on its own stigmas. Besides autopollination caused by rubbing, I have also observed two other methods of autopollination.

WHEN TO PERFORM THE OPERATION

It has been found that flowers operated upon about twenty-four hours before blooming, but pollinated at the time of opening, set fruits almost invariably. Flowers operated upon and also pollinated twenty-four hours before blooming did not set

Pods. If operated upon and also pollinated at the time of blooming a small percentage of the flowers so treated produced fruits. It is quite probable that the proper length of time to be allowed between operation and pollination depends to a certain extent upon the relative stage of development of the style at the time the operation is performed. Those flowers which produced fruits invariably when operated upon about twenty-four hours before blooming and pollination, were the typical ones; namely, those in which the stigmas were only about 1 to 5 millimeters below the opening of the staminal tube.

SIGNIFICANCE OF THE PRESENT OBSERVATIONS

The results of the foregoing observations would seem to have an important bearing on organic evolution and on methods of plant breeding. From the latter standpoint, the importance of the results of operation and the setting of seeds of the flowers operated upon is obvious, and further discussion of this point is deemed unnecessary. Suffice it to say that a variety that is otherwise incapable of producing seeds has been forced to fruit. It is the theoretical bearing of the results that I desire to discuss more fully. It is generally believed that plants bearing hermaphrodite flowers, of which *Hibiscus* plants are examples, will become after a time dioecious individuals. Just which changes first, the morphology or the physiology of the sexual organs, is not well known. The case of flowers with hidden stigmas, reported in this paper, would apparently provide a point in support of the theory of morphological priority.

The present observations also have a bearing upon the effect of stock on scions in general, and on the sex of the latter in particular. That the stock affects its scion is well known in horticulture. The effect has been varied. Published results on this point, however, do not seem to include the effect of the stock on the sex of the scion. Cases of known degrees of barrenness and productivity induced by budding or grafting are common, but these phenomena are not necessarily dependent on the nature of sex organs. In the present work it has been pointed out that a variety of *H. rosa-sinensis*, which produces anatomically imperfect hermaphrodites and impotent pollen when grown on its own roots, produces perfect hermaphrodites and potent pollen when budded on another variety. This fact would support the theory that perfect or imperfect hermaphroditism has much to do with physiological causes. Doctor Stout, of the New York Botanical Garden, who kindly consented to

criticize this paper, pointed out that the bud which was inserted in the Native Red Single might have been a bud mutation. He suggested a repetition of the budding, using many buds of the Prisoner variety, and checking the observation on the effect of budding on the Prisoner flowers. The results of this experiment will be reported in a future paper.

Finally, I wish to point out the possibility that the effect of the operation reported in this paper (of rendering receptive stigmas that are otherwise nonreceptive) belongs to the class of phenomena known as sex change or, better still, change of sex expression, due to mutilation; as, for example, the production of hermaphrodite flowers in a so-called "male" papaya following decapitation, or the conversion of sterile banana flowers into fruit-bearing, though seedless, individuals following an accidental mutilation at the top of the false stem of the plant.⁴

The results of the present observations would indicate another way of obtaining fruit from male papayas; that is, by budding, or grafting buds of the male plant on more vigorous individuals. The papaya is known to lend itself to grafting and other methods of asexual propagation.

⁴ Mendiola, N. B., Effect on banana fruit of premature appearance of the inflorescence, Philip. Agr. 10 (1922) 299-300.

ILLUSTRATIONS

PLATE 1

FIG. 1. A typical flower of *Hibiscus*, variety Prisoner, not showing the stigmas inside the staminal column.

2. Terminal half of staminal column split, exposing the hidden stigmas.

3. Appearance of infertile ovary of a typical flower at the time of the premature fall of the ovary.

FIGS. 4 to 8. Different steps in the operation of the staminal column of a bud, twenty-four hours before opening, to expose the stigmas; 4, typical bud twenty-four hours before opening; 5, top of corolla removed with a pair of small scissors; 6, anthers of the part exposed have been removed; 7, point of staminal column over stigma has been cut off and walls of remaining top of column bent aside to expose the stigmas, enlarged; 8, appearance of stigmas twenty-four hours after operation. At this stage the stigmas are functional with cross-fertile pollen.

9 to 11. Details of flowers of *H. rosa-sinensis*, var. Woodrow Wilson; 9, normal stigmas of a typical flower; 10, an abnormal flower from which the petals were cut to show the staminal tube. This was split open to show the much-delayed pistil. The stigmas were several centimeters below the top of the tube at the time of blooming; 11, similar to fig. 10, except that the stigmas are nearer to but still a few centimeters below the top of the tube.

12 to 14. Details of flower of *H. rosa-sinensis*, var. Two-Days; 12, a typical flower of the variety, showing exposed, normal stigmas; 13, part of a staminal tube, inside of which is the pistil which failed to come out; 14, similar to fig. 13, except that the stigmas came out by breaking through the walls of the tube instead of normally appearing above the pore of the tube.

PLATE 2

FIGS. 1 to 5. Flower buds of variety Prisoner showing different kinds and degrees of attacks of insects. In fig. 5 the top of a stigma, exposed on account of the attack, is barely visible.

FIG. 6. A clearer case of the condition shown in fig. 5.

FIGS. 7 to 13. Similar to figs. 1 to 6, but relating to different varieties, as follows: 7, Unknown-3; 8, Unknown-4; 9, Unknown-3; 10, (Deep Pink \times Hawaiian Salmon)-4; 11, Unknown-12; 12, Hawaiian Pink; 13, Unknown-6.

PLATE 3

FIGS. 1 to 11. Styles of different flowers of Prisoner growing on their own roots, showing variability in distance between stigmas and opening of the staminal tube. By referring to Table 1, the frequency distribution of each of the distances shown may be learned.

12 to 21. Similar to figs. 1 to 11, except that the styles shown were from a budded plant. (See also Table 1 for frequency distribution of different types.)

PLATE 4

FIG. 1. *Ornithoptera nephareus* Gray in the act of pollination.

2. Underside of one of the hind wings showing pollen grains on the portion which comes in contact with pollen and stigmas.
3. Ventral side of abdomen showing pollen grains.

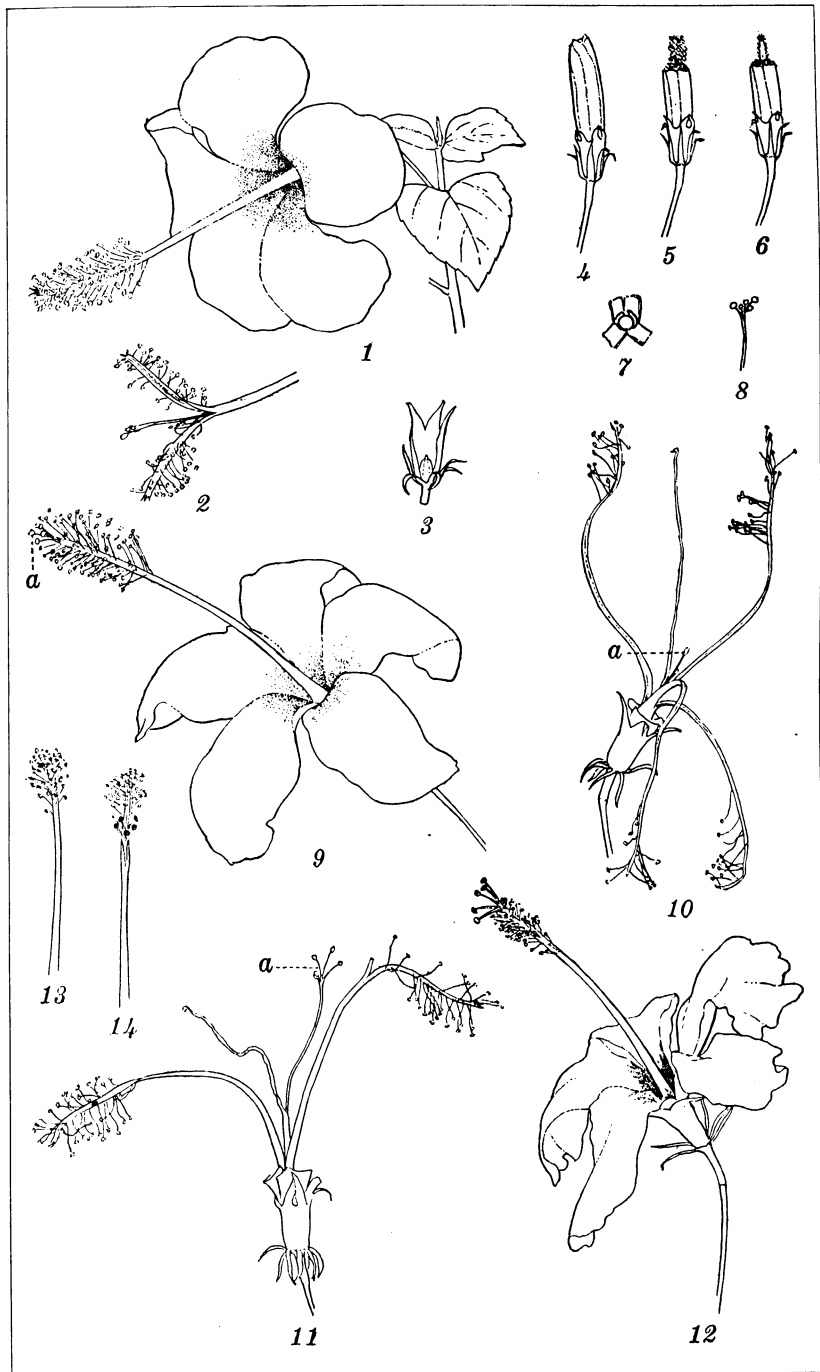


PLATE 1.

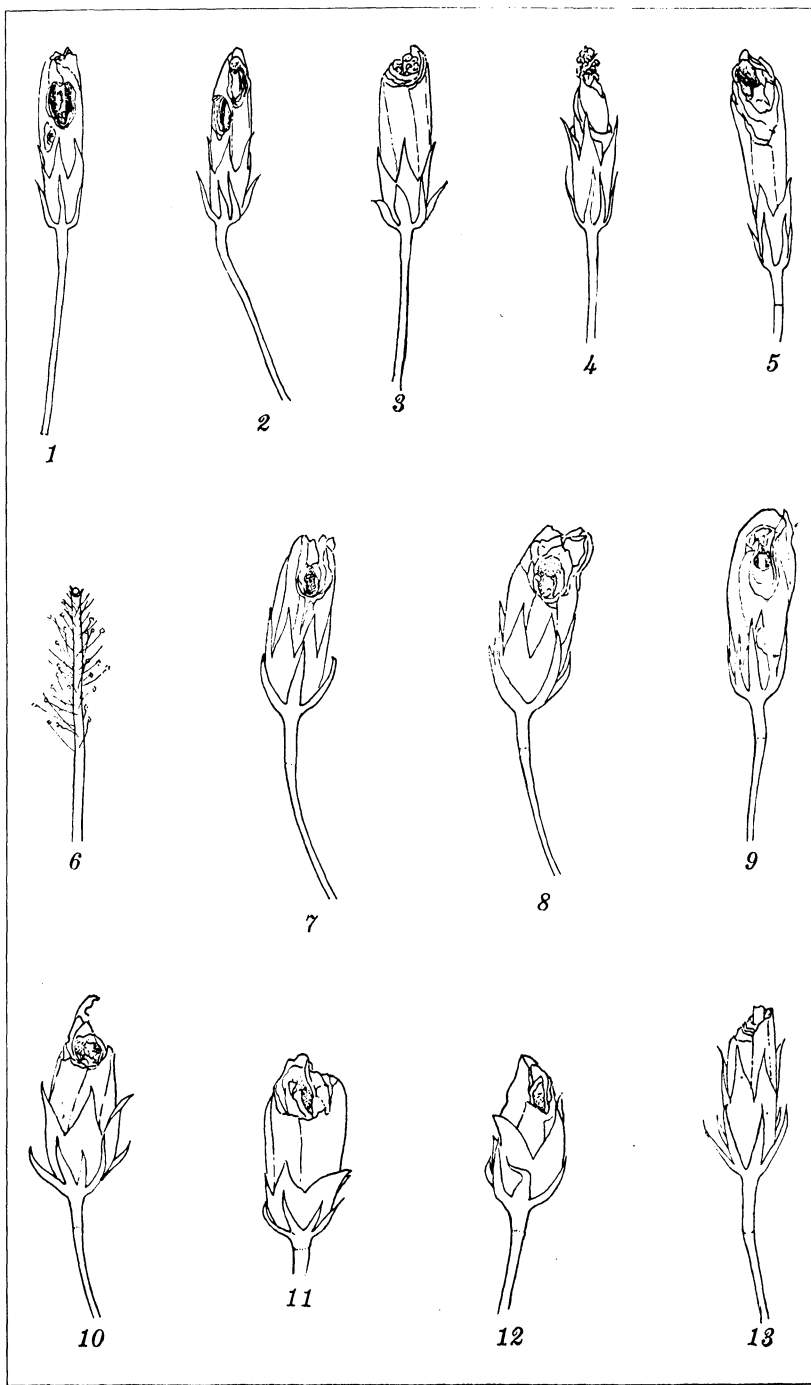


PLATE 2.



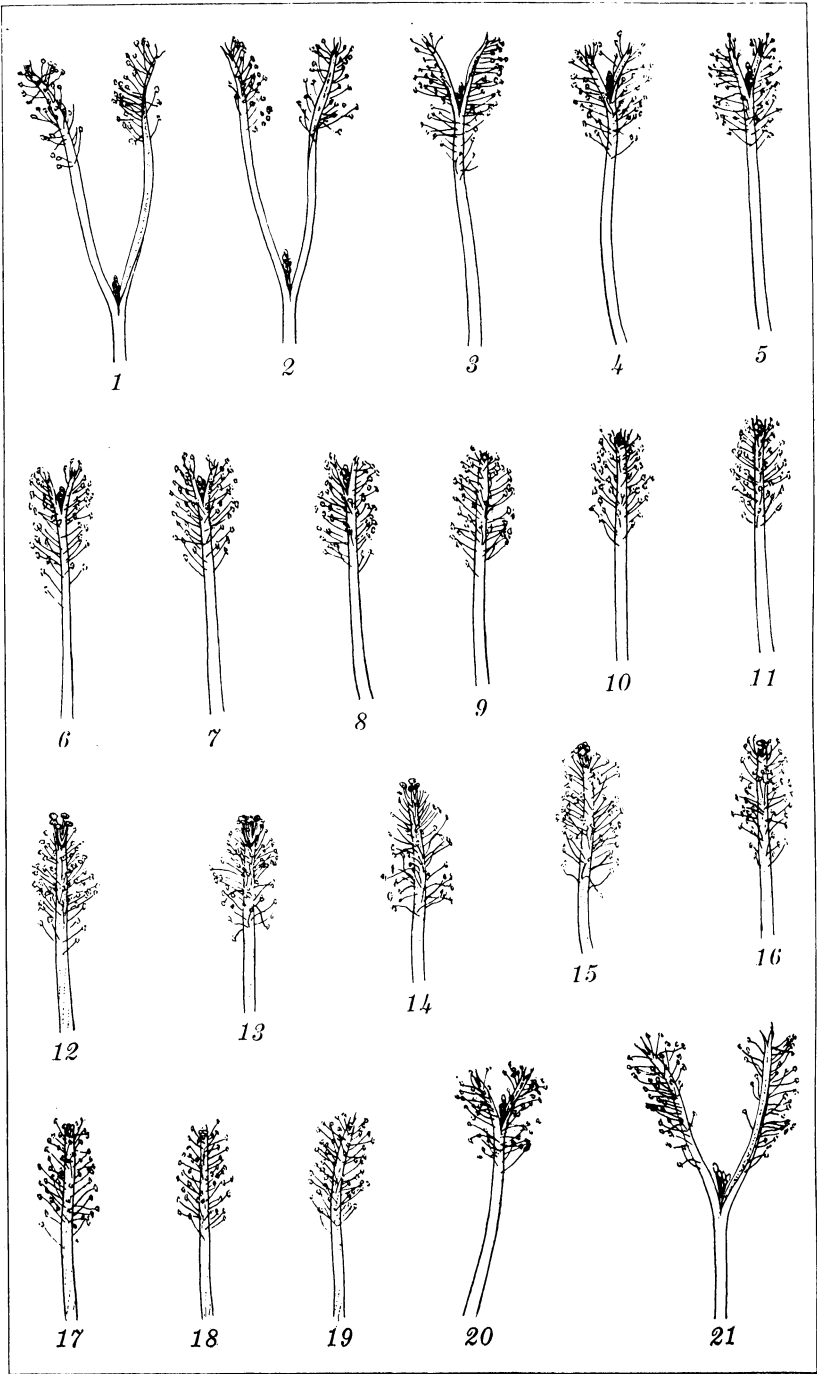


PLATE 3.



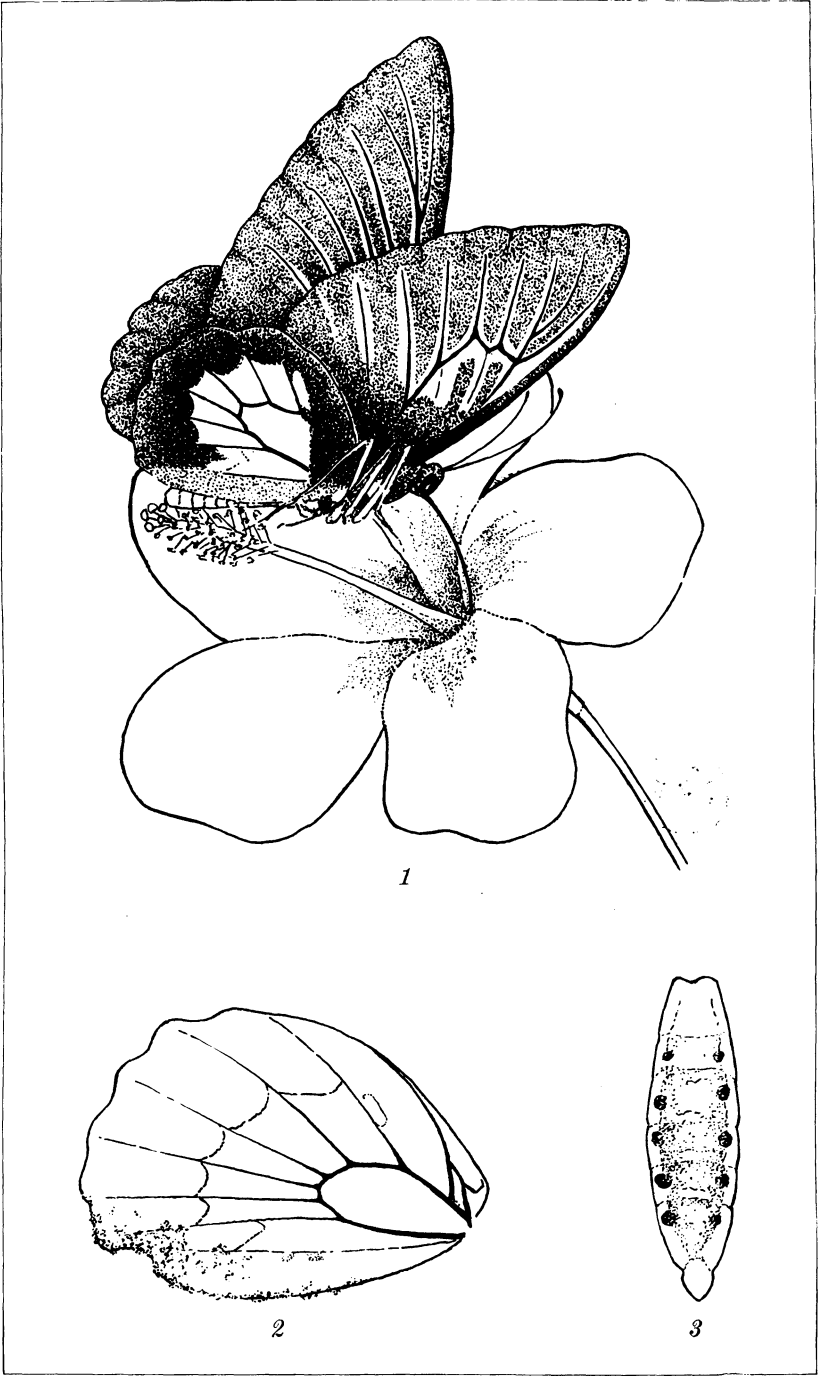


PLATE 4.



DETERIORATION OF ABACÁ (MANILA HEMP) FIBER THROUGH MOLD ACTION

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TEN PLATES AND TWO TEXT FIGURES

INTRODUCTION

HISTORICAL

Defective Manila hemp was first noted in 1902, when large quantities of the material reached the United States. The American expert who investigated the trouble attributed it to long storage of the fiber.

After that time, unsound fiber did not attract any particular attention until the latter part of 1920, when complaints from some hemp dealers were received. However, proper consideration was not given the matter until the early months of 1921, after the English importers had received many more shipments of similarly defective material.

Inquiries and observations were then made at the local warehouses where Manila hemp is stored, where it was learned, first, that defective fibers are in many cases found in low grades, such as those from J to DM; second, that they very seldom occur in higher grades, such as those from A to H; third, that defective fibers come from nearly all abacá-growing provinces and are not confined to any specific locality, although the majority of complaints have been against fiber coming from the Bicol region; fourth, that because of the sudden drop in the price of commodities after the World War, enormous quantities of fiber were kept in storage in the local warehouses for from one to two years, or even longer, with the result that in the latter part of 1920 defective Manila hemp became so abundant as to attract the attention of the English importers; and fifth, that sometimes fiber samples that are apparently normal and strong when shipped from the Islands are found weakened and damaged when received in London.

Since then samples of unsound fiber have been sent in by English importers, local fiber dealers, Government fiber inspectors, and many others, requesting information and comment on the causes of the trouble.

In collaboration with Mr. H. Atherton Lee, then mycologist of the Bureau of Science, the preliminary experiments leading to the preparation of this paper were worked out. Various organisms, such as *Aspergillus flavus* Link, *Aspergillus niger* van Tieghem, *Penicillium glaucum* (Link?) Brefeld, *Rhizopus nigricans* Ehrenberg, *Leptosphaeria* sp., one sterile fungus, and four kinds of bacteria were isolated from the diseased fibers. The check cultures from normal fiber yielded, to a very much less degree, the same microorganisms, except *Leptosphaeria* and the sterile fungus.

In order to test the action of these organisms on sound fibers, test tube cultures of moist Manila hemp (grades H and J), absorbent cotton, and filter paper were prepared and inoculated after steam sterilization. After the tubes had been kept two months at room temperature (27 to 30° C.) it was found that *Aspergillus flavus*, *A. niger*, *Leptosphaeria* sp., and the sterile fungus had caused deterioration to about equal extent in Manila hemp and filter paper, but to a very much less extent in the absorbent cotton. The deterioration was so great that the weakened condition could be detected by the hand test alone.

During the progress of the preliminary experiments the results of English investigations on the same subject were noted from time to time, in either published articles or unpublished manuscripts. Some of these results are cited and discussed in this report.

PRESENT WORK

The objects of the present work were to determine the effect of molds on the fiber and to formulate, if possible, practical methods of control.

DESCRIPTION OF DETERIORATED FIBER

Defective fiber is characterized by weakness, brittleness, sometimes a dark color, and a musty odor which is stronger in moist fiber than in dry. Irrespective of grade, it loses the luster natural to normal, well-cleaned fiber. When badly damaged and dry, it is so weak and brittle that it can easily be crushed into a powdery mass in the hand; but when the damage is less, the de-

terioration in tensile strength may be so slight as to escape detection by the hand test alone, in which case the loss in strength can be determined only by machine testing.

As a general rule, the color reveals its actual condition; that is, in almost all cases in the same class of fibers the light-colored hanks are sound and the dark-colored ones are damaged.

Although in the majority of cases defective fiber is darker than normal, color cannot always be considered as definitely associated with unsoundness, for examination of hundreds of samples of supposedly damaged material in these grades has shown that light and dark-colored fibers in the same hank may be equally deteriorated by various organisms, or the dark-colored fiber may even be normal and the light-colored deteriorated; in the latter cases dark-colored fiber (streaky) was found which was not infected at all, but had a natural color resulting from the dark spottings or patches¹ generally present on the outer part of the outer leaf sheaths of the abacá plant, and the light-colored fiber was infected with molds alone. (See Plate 10.) Owing to the presence of sap (possibly containing tannin) which remains after improper drying of the fibers just after stripping, they may have a buff color instead of being white, and still be not in the least inferior in so far as the tensile strength is concerned. In such case color cannot, therefore, be hastily taken as a sure sign of deterioration, though damaged fiber does have a certain dull and dirty shade, a characteristic which will not be passed unnoticed by a keen-eyed, experienced fiber man. Next to lower tensile strength and harder texture, a dull, dirty, dark color, therefore, constitutes another criterion for deciding that a given fiber has deteriorated.

It is interesting to note in this connection that deterioration is not always general throughout the entire length of the fiber, but that a single strand may be defective in the middle and sound at the base and tip, and vice versa.

CAUSAL ORGANISMS

ISOLATION TECHNIC

Using potato glucose agar +1 and beef bouillon +1 as culture media numerous isolations of the organisms present on

¹ In some varieties, as in what is called "abacang bayan," in San Antonio, Loños, Laguna, such patches are natural while in others they are the result of pathological infections, as in the case of *Marasmius*.

stored fibers were made from material obtained from local warehouses in which fibers from all abacá-producing provinces are held for some time before they are shipped abroad.

From damaged fiber, grade J, sent in by Smith, Bell and Company, Limited, and other local abacá dealers, strands were cut into sections of about 1 centimeter long which, after having been moistened with tap water to allow immediate and uniform action of the disinfectant, were soaked in a 1:1,000 solution of mercuric bichloride for one minute and then washed four times in sterile water, after which they were picked up one by one with sterile forceps, plated in five plantings onto each of ten Petri dishes of potato glucose agar +1, and one planting in each of ten bouillon tubes. The cultures were then set aside and incubated at room temperature (27 to 30° C.).

After twenty-four hours it was found that all of the bouillon tubes were clouded, indicating that microorganisms had already started to develop, and thirty of the plate cultures had produced bacterial colonies, but no fungus. From these bacterial cultures dilution plates were made on potato glucose agar +1. On the following day the dilution plates gave rise to three types of bacterial colonies—one grayish, one creamy buff, and one wax brown, the grayish predominating—while twenty-five plantings on the original plates showed fungal growth; transfers were made from the last-named, as well as from the bacterial species, to be used for further studies. A detailed study of the fungal cultures revealed the presence of *Aspergillus flavus*, *A. fumigatus*, *A. niger*, and *Chaetomium funiculum*.

A second series of tests, using the same strength of mercuric bichloride but increasing the interval of soaking from 1 minute to 2, 3, 4, and 5 minutes, respectively, was then made. After forty-eight hours of incubation the first set gave 40 per cent positive results; the second, 25 per cent; the third, 5 per cent; and the fourth was entirely negative. The fungi obtained included all the species isolated from the first series. Repetition of the experiment gave practically the same results, with the bacterial colonies appearing first.

In a subsequent series of isolation experiments the method of eliminating external organisms employed by Altson (unpublished report) was tried. The 1-centimeter sections of damaged fiber were subjected to prolonged washing in running tap water,

followed by rinsing and washing in several changes of sterile water, then plated one by one on plates of potato glucose agar +1, five plantings to each. The experiment was duplicated, using sections from sound fiber of the same grade for check. As was expected, the types of microörganisms isolated from the damaged fiber were greatly increased in number, while from the sound material, curiously, practically the same ones were obtained, although to a very much less degree, the tests being not more than 20 per cent positive. Repetition of the experiment, using samples from different warehouses, gave almost the same results. In the majority of cases bacteria appeared in association with the molds.

The following is a list of the organisms,² excluding bacteria, that were isolated more or less uniformly from numerous samples of disintegrated fiber, mostly grade J, *Aspergillus flavus*, *A. fumigatus*, and *A. niger* being the most prevalent:

<i>Aspergillus flavus</i> Link.	<i>Chaetomium elatum</i> Kunze.
<i>Aspergillus fumigatus</i> Fresenius.	<i>Chlamydomucor racemosus</i> Brefeld.
<i>Aspergillus glaucus</i> Link.	<i>Penicillium glaucum</i> (Link?) Brefeld.
<i>Aspergillus niger</i> van Tieghem.	<i>Rhizopus nigricans</i> Ehrenberg.
<i>Aspergillus wentii</i> Wehmer.	<i>Rhizopus oryzae</i> Went.
<i>Chaetomium funicolum</i> Cke.	Yeast, black (possibly <i>Torula nigra</i> Guill.).
<i>Chaetomium olivaceum</i> C. & E.	Yeast, red (possibly <i>Torula</i>).
<i>Chaetomium olivaceum</i> var. <i>chartarum</i> Ehrenberg.	

Aside from the species listed above two kinds of sterile fungi and *Alternaria* sp. were isolated also, but these were discarded for lack of frequent association with deteriorated fibers.

INOCULATION EXPERIMENTS

The above organisms were inoculated on abacá fiber to ascertain their relations to the weakness of the fiber.

As it was believed that moisture plays an important part in the destruction of the fibers, two sets of inoculation tests were carried out, using dry fiber in the first and moist fiber in the second.

² These were identified by comparing their growth characteristics with various published descriptions, particularly those given in Lafar's Technical Mycology and Ellis and Everhart's North American Pyrenomycetes.

Methods and technic.—Strands, 50 centimeters long, were cut from a hank of sound abacá fiber, grade J. These were divided into eighty-five uniform samples of about 2.5 grams, each of which was folded twice, put into an ordinary test tube provided with a cotton plug, and then sterilized in the autoclave for one hour at 102° C. That this was sufficient for sterilization was indicated by negative results secured on culturing ten of the samples.

While the sterility of the specimens was being tested, their moisture content was determined by taking the samples in the last five test tubes, weighing separately, and then drying to constant weights at 102° C. in an oven. The results show that the fiber samples under experimentation contained on the average 11.7 per cent moisture.

TABLE 1.—*Effect of molds on air-dry, sterile abacá fiber, grade J1.*

Tube No.	Inoculum.	Color. ^a	Average tensile strength. ^b	Deterioration.
				<i>Per cent.</i>
1 to 4....	<i>Aspergillus flavus</i>	Light buff.....	28.4	23.3
5 to 8....	<i>Aspergillus fumigatus</i>	do.....	26.2	29.2
9 to 12....	<i>Aspergillus glaucus</i>	do.....	37.7	
13 to 16....	<i>Aspergillus niger</i>	do.....	31.1	16.0
17 to 20....	<i>Aspergillus wentii</i>	do.....	38.7	
21 to 24....	<i>Chaetomium elatum</i>	do.....	32.9	11.0
25 to 28....	<i>Chaetomium funiculum</i>	do.....	31.3	15.4
29 to 32....	<i>Chaetomium olivaceum</i>	do.....	35.0	5.4
33 to 36....	<i>Chaetomium olivaceum</i> var. <i>chartarum</i>	do.....	36.3	1.8
37 to 40....	<i>Chlamydomucor racemosus</i>	do.....	42.0	
41 to 44....	<i>Penicillium glaucum</i>	do.....	37.8	
45 to 48....	<i>Rhizopus nigricans</i>	do.....	38.0	
49 to 52....	<i>Rhizopus oryzae</i>	do.....	39.1	
53 to 56....	Yeast, black.....	do.....	40.3	
57 to 60....	Yeast, red.....	do.....	39.7	
61 to 80....	Control (check).....	do.....	37.0	

^a The colors indicated here and elsewhere in this paper are those of Ridgway's Color Standards and Color Nomenclature. Washington (1912).

^b Average breaking strain in kilograms per gram meter of twenty samples.

The first series of inoculations of sterile fiber samples was carried out on August 1, 1923. With the pure cultures of the fifteen kinds of organisms obtained from the isolation experiments aforementioned, infection was artificially made in all of the remaining eighty sterile fiber samples, except the last twenty which were kept as check. There were, therefore, five

test tubes of fiber to each kind of organism—four infected and one sterile, as check. The infection was done by transferring with a sterile platinum needle bits of the mycelial threads, or masses of spores as the case may be, of each individual culture into the fiber samples in test tubes. As soon as the needle was infected by touching the fresh culture, it was thrust many times into the fiber strands in the test tubes, so as to make the infection of the fibers as nearly uniform and as thorough as possible. The entire set was then set aside and allowed to incubate under ordinary room conditions with a temperature ranging from 27 to 30° C.

TABLE 2.—Effect of molds on moist, sterile abacá fiber, grade J1.

Tube No.	Inoculum.	Color.	Average tensile strength.*	Deterioration.
				Per cent.
1 to 4....	<i>Aspergillus flavus</i>	Warm buff with patches of mouse gray.	21.6	36.2
5 to 8....	<i>Aspergillus fumigatus</i>	do.....	11.5	66.0
9 to 12....	<i>Aspergillus glaucus</i>	do.....	27.2	20.0
13 to 16....	<i>Aspergillus niger</i>	do.....	21.9	35.3
17 to 20....	<i>Aspergillus wentii</i>	do.....	28.0	14.6
21 to 24....	<i>Chaetomium elatum</i>	Vinaceous buff.....	21.9	35.5
25 to 28....	<i>Chaetomium funiculum</i>	Colonial buff.....	16.2	52.2
29 to 32....	<i>Chaetomium olivaceum</i>	Deep olive buff.....	18.8	44.7
33 to 36....	<i>Chaetomium olivaceum</i> var. <i>chartarum</i>	do.....	19.9	41.3
37 to 40....	<i>Clamydomucor racemosus</i>	Warm buff.....	22.9	32.4
41 to 44....	<i>Penicillium glaucum</i>	do.....	24.8	27.0
45 to 48....	<i>Rhizopus nigricans</i>	do.....	36.3	-----
49 to 52....	<i>Rhizopus oryzae</i>	do.....	36.3	-----
53 to 56....	Yeast, black.....	Slate gray.....	35.7	-----
57 to 60....	Yeast, red.....	Livid pink.....	39.3	-----
61 to 80....	Control (check).....	Cream buff.....	34.0	-----

* Average breaking strain in kilograms per gram meter of twenty samples.

Subsequently, another series of inoculations was started, duplicating the first in every respect except in the moisture content of the fibers. In the first series (Table 1) air-dry fiber with a moisture content of only 11 to 12 per cent was used, whereas in the second (Table 2) wet fiber was used; the latter was prepared by adding with a sterile pipette as many cubic centimeters of sterile water as there were grams of the fiber

samples. Two months later (October 1, 1923) the necessary observations were made, taking the dry series first.

Results.—In color no appreciable difference was noted in the dry series between the inoculated and the control; it was only in the texture that the two differed; that is, those inoculated with *Aspergillus flavus*, *A. fumigatus*, *A. niger*, *Chaetomium elatum*, *C. funiculum*, and *C. olivaceum* were not so soft as were the control and the rest of the samples inoculated with other organisms. Neither did the hand tests reveal any difference in the tensile strength of the samples, a condition which favored the belief that none of the organisms used could appreciably damage artificially infected, sterile, dry fiber. Machine tests made on the Louis Shopper machine, however, indicated that with the first two organisms, at least, the deterioration was significant. With the remaining organisms the results given apparently lie within the limits of experimental error.

On the other hand, the deteriorative effect of the molds was much more readily observed on the moist fiber, both in tensile strength and in color (Table 2). The inoculated fibers were darker than the control, although not all the dark-colored inoculated ones were invariably weaker than the light-colored. Again, attention is called to the fact that dark color is not always correlated with unsoundness or a damaged condition of the fiber. The testing data indicate that at least ten of the organisms may cause considerable or marked deterioration in moist fiber.

REISOLATION AND IDENTIFICATION

From the inoculation experiments that gave positive results reisolutions were made on potato glucose agar +1. These reisolutions yielded the organisms originally used.

VARIOUS BELIEFS AS TO THE CAUSE OR CAUSES OF DAMAGE, AND EXPERIMENTS THEREON

COMPARATIVE EFFECTS OF MOLDS ON ABACÁ AND CANTON FIBERS

It has been suggested that adulteration of abacá fiber with other kinds of fiber, such as canton and pacol, might lead to the appearance of a considerable amount of damage, the idea being that canton might deteriorate more readily than abacá. This assumption was incidentally favored by the fact that fibers

of both canton and pacol are by nature weaker than abacá fiber and are also produced in the Bicol provinces whence a large amount of unsound abacá fiber has come. To test the comparative effect of molds in causing deterioration of abacá and canton, another series of inoculations was conducted, using both completely moist abacá and canton fibers of the same grade (F1) as media and the pure cultures of all the organisms proved to cause deterioration as inocula. Care was exercised to make the samples as nearly uniform as possible and to subject them to the same conditions and treatment. With the controls the inoculated specimens were set aside to incubate at room temperature (27 to 30° C.). Forty days later observations were made, as in the previous experiments, taking the tensile strength of the fiber on the machine. The results are given in Table 3.

In this experiment there is no indication that molds cause greater deterioration in canton than in abacá; in fact, in this particular case canton showed somewhat less deterioration than did abacá. Since the test was carried out only on one sample of each product, however, the results should not be considered by any means conclusive, for different results might be obtained from plants from different localities under other conditions.

TABLE 3.—*Comparative tensile strength of abacá and canton fibers affected by molds.*

Tube No.	Inoculum.	Average tensile strength.*	
		Abacá.	Canton.
1 to 5	<i>Aspergillus flavus</i>	19.4	18.9
6 to 10	<i>Aspergillus fumigatus</i>	16.6	12.9
11 to 15	<i>Aspergillus glaucus</i>	25.9	22.7
16 to 20	<i>Aspergillus niger</i>	26.8	20.7
21 to 25	<i>Aspergillus wentii</i>	27.1	17.3
26 to 30	<i>Chaetomium elatum</i>	23.9	24.9
31 to 35	<i>Chaetomium funiculum</i>	14.9	11.6
36 to 40	<i>Chaetomium olivaceum</i>	22.9	13.4
41 to 45	<i>Chaetomium olivaceum</i> var. <i>chartarum</i>	23.7	19.1
46 to 50	<i>Chlamydomucor racemosus</i>	34.4	24.4
51 to 55	<i>Penicillium glaucum</i>	31.6	23.3
Mean of the control		39.35±0.6	29.3 ±0.4
Mean of the infected fiber		23.9 ±1.2	18.5 ±0.4
Difference of the means		15.4 ±1.4	10.9 ±0.6
Per cent of deterioration		39.1	37.2

* Average breaking strain in kilograms per gram meter of twenty samples.

ADMIXTURES OF FIBERS FROM INNER AND OUTER SHEATHS

Harvey-Gibson,(4) in reporting on the findings from his experimentation, expressed the belief that the defective nature of Manila hemp is partly due to (a) admixture of vascular bundles and parenchyma, which would not be present if only the outside part of the petiole were used, and (b) admixture of fiber stripped from the less mature leaf sheaths from the innermost part of the pseudostem with that from the more mature outer sheaths.

While it appears true from tests made by both Espino(3) and myself that fibers from the middle portion of the leaf sheath are weaker than are those from the sides of the same leaf sheath, and that fibers from the innermost leaf sheath are weaker than are those from either the intermediate or the outermost leaf sheaths, these weaker fibers cannot be classified as damaged fibers, in as much as they compare favorably in tensile strength with normal, well-cleaned fiber. Apparently the fibers from intermediate leaf sheaths are also stronger than those from the outermost or innermost sheaths as indicated by the work of Espino(3) and by a number of tests made by myself on a single plant. This comparative weakening has been ascribed by various authors to the presence on fibers from the outermost leaf sheaths of "peculiar, thick, strongly silicified plates, known as stegmata,"(5) and to a less-developed condition of the fibers in the innermost sheaths.

DETERIORATION OF WELL-CLEANED FIBER FROM DIFFERENT LEAF SHEATHS

In order to determine whether the age of the fiber has any relation to the rate of deterioration caused by cellulose-digesting organisms the following experiment was carried out.

An immature nonfruited but well-developed stalk of the Sinibuyas variety of abacá was cut, and the fibers from each leaf sheath were stripped separately with a nonserrated knife. The fibers were numbered from 1 to 18 inward, from the outermost (oldest) to the innermost (youngest) sheath. From each group, three samples, each 0.5 meter long and weighing about 2.5 grams, were cut, coiled into a ring with a diameter of about 1 decimeter, placed in Petri dishes, completely moistened with tap water, and then sterilized for one hour in an oven at about

102° C. Two of the three plates of each of the eighteen groups were then inoculated on September 13, 1924, with spores of *Aspergillus fumigatus* in pure culture and, with the triplicates as check, incubated in an oven with a temperature ranging from 38 to 40° C.

Thirty days later, the necessary observations were made. From each sheath ten representative samples of the inoculated, as well as of the control, were prepared, weighed separately, the tensile strength of each tested on the machine, and the percentage of stretch per 20 centimeters distance noted. The results are given in Table 4.

TABLE 4.—Comparative rate of deterioration by *Aspergillus fumigatus* of well-cleaned fibers from different sheaths of a single plant.*

Sheath, numbered from outermost.	Average tensile strength. ^b		Average stretch. ^c		Deterioration.		Mean deterioration of the six outermost, six middle, and six innermost leaf sheaths.	
	Inocu- lated.	Check.	Inocu- lated.	Check.	Strength.	Stretch.	Strength.	Stretch.
			<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
1	36.9	41.4	2.7	3.4	10.8	20.9		
2	29.4	36.2	1.6	2.1	18.8	23.1		
3	30.2	44.3	1.7	2.1	31.9	18.1		
4	34.7	50.2	2.2	2.9	30.9	25.3		
5	30.8	47.6	2.2	3.0	35.4	26.6		
6	31.8	42.3	2.0	2.6	24.8	23.5	24.7±1.4	22.2±0.8
7	32.7	39.1	2.2	3.1	16.3	26.5		
8	30.1	49.6	2.2	2.8	39.2	22.0		
9	36.9	45.1	2.1	2.5	18.3	18.1		
10	30.5	41.7	2.1	2.6	26.8	18.8		
11	34.5	52.2	2.0	2.9	33.9	30.2		
12	32.9	46.3	2.1	2.8	29.0	26.4	27.2±1.8	23.8±1.0
13	35.1	45.5	2.2	3.0	22.9	25.8		
14	33.8	43.8	2.1	2.6	22.9	21.1		
15	32.5	50.7	2.1	2.8	35.8	25.6		
16	32.1	50.5	2.0	2.8	36.5	26.4		
17	30.3	49.1	1.9	2.8	38.2	32.1		
18	30.2	45.4	2.3	3.0	33.5	22.7	31.3±1.6	25.5±0.6
Mean difference between first and second groups.....							2.5±2.3	1.6±1.4
Mean difference between second and third groups.....							4.2±2.4	1.7±1.3
Mean difference between first and third groups.....							6.7±2.2	3.3±1.1

* This plant being immature, the innermost fibers are naturally not so developed as are the outermost.

^b Average breaking strain in kilograms per gram meter of twenty samples.

^c Average percentage of stretch of the fiber per 20-centimeter distance of the sample.

DETERIORATION OF POORLY CLEANED FIBER

It has been the opinion among fiber men who are more or less conversant with the subject that only fibers of the poorly cleaned grades deteriorate; that is, fibers of excellent or good cleaning ranging from grade A to grade S are thought to be immune, while partially cleaned fibers, from grade I down, are susceptible. That this view should be modified is indicated by the considerable losses sustained in well-cleaned fiber in the tests reported above, as well as by observations made on deterioration under commercial conditions.

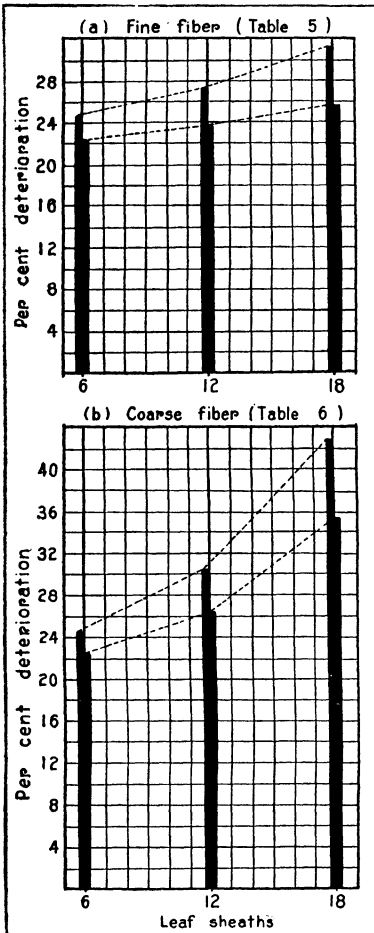


FIG. 1. Showing graphically the rôles that age and poor or partial cleaning of fiber play in relation to deterioration. Left column, percentage of deterioration in strength; right column, percentage of deterioration in stretch.

employed, fiber of a better quality is produced. Generally the strippers in these localities classify their fiber into the following

three grades, which conform in principle with the Fiber Standardization Board's standard:

Sheath.	Grading.
1 to 6 (outermost)	Third class (S1-H).
7 to 12 (intermediate)	Second class (C-E).
13 to 18 (innermost)	First class (A-B).

According to this grading, fibers of the First class are the youngest; fibers of the Second class, the intermediate; and fibers of the Third class, the oldest; but, when cleaning is poor, or only partial, the fibers are classified as fair, medium, and coarse.

On the other hand, in the Bicol and Visayan provinces as well as in Mindanao, where both kinds of stripping knives are used (but usually the serrated), the strippers do not separate the fibers into grades as they do in Luzon, but mix them together and leave them for the middlemen or consumers to classify. Following the standard adopted by the Fiber Standardization Board these fibers are ultimately graded as A, B, C, etc. (United Kingdom grades), in the case of partially cleaned fibers or fibers stripped with the serrated knife.³

In order to find out whether or not poor or partial cleaning of the fiber favors deterioration another set of inoculation experiments was carried out beginning September 13, 1924, using partially cleaned fiber or fiber stripped with the serrated knife. This experiment was a duplicate of that recorded in Table 4, except that in this case coarser fiber, or fiber stripped with the serrated knife, was used.

After thirty days of incubation in an incubator with a temperature ranging from 38 to 40° C. the necessary observations were taken and the results are shown in Table 5.

The results show that, all things being equal, the coarser fiber sustained somewhat greater loss in deterioration, both in tensile strength and in stretch, when infected with the cellulose-digesting organism than did the finer fiber. This is substantiated by taking the mean percentages of deterioration of the fine fiber (Table 4) which are approximately 27.8 and 23.8, for strength and stretch, respectively, and comparing them with those of the coarse fiber amounting to approximately 32.7 and

³ For reference in grading abacá fiber see Administrative Order No. 44, Bureau of Agriculture, P. I., 1924.

28.0. Similarly, there is shown a distinct tendency for the fibers to deteriorate more rapidly from the outermost to the innermost.

TABLE 5.—Comparative rate of deterioration by *Aspergillus fumigatus* of coarse fibers from different sheaths of a single plant.^a

Sheath, numbered from outermost.	Average tensile strength. ^b		Average stretch. ^c		Deterioration.		Mean deterioration of the six outermost, six middle, and six innermost leaf sheaths.	
	Inocu- lated.	Check.	Inocu- lated.	Check.	Strength.	Stretch.		
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
1.....	29.3	38.9	2.6	3.7	24.6	29.2		
2.....	30.4	42.0	2.5	3.3	27.5	24.9		
3.....	29.3	40.7	2.7	3.7	28.1	27.3		
4.....	29.4	35.1	2.2	2.6	16.2	13.5		
5.....	32.2	45.0	2.0	2.5	26.2	20.6		
6.....	34.5	49.9	2.5	3.2	30.8	22.2	24.7±1.0	22.2±1.4
7.....	36.6	46.3	2.7	3.7	21.2	26.5		
8.....	31.6	50.1	2.2	3.2	36.9	30.0		
9.....	35.6	48.5	2.7	3.5	26.8	22.5		
10.....	31.3	44.5	2.6	3.2	29.6	19.7		
11.....	31.0	44.6	2.4	3.1	30.4	21.3		
12.....	28.3	45.6	2.2	3.6	27.8	40.3	30.5±1.5	26.4±1.7
13.....	25.2	42.6	2.4	3.0	40.9	38.9		
14.....	32.2	54.7	2.4	4.1	41.2	42.1		
15.....	28.7	46.2	1.9	2.8	38.0	30.8		
16.....	27.5	48.3	2.0	3.2	43.2	35.8		
17.....	22.6	53.1	1.7	3.2	57.3	46.0		
18.....	24.5	51.0	2.0	2.8	51.0	30.1	43.0±1.1	35.5±1.1
Mean difference between first and second groups.....							5.8±1.5	4.2±2.2
Mean difference between second and third groups.....							12.5±1.8	9.2±2.0
Mean difference between first and third groups.....							18.3±1.1	13.3±1.8

^a This plant being immature, the innermost fibers are naturally not so well developed as are the outermost.

^b Average breaking strain in kilograms per gram meter of twenty samples.

^c Average percentage of stretch of the fiber per 20-centimeter distance of the sample.

DISEASES OF THE ABACÁ PLANT

The view has been expressed that bunchy-top (root rot) and heart rot, which are serious diseases of the abacá plant in certain districts of the Philippines, may have some connection with deterioration of the fiber. To throw some light on the relative strength of fiber from diseased and healthy plants five plants affected with bunchy-top in varying stages of infection and five healthy plants, all of approximately the same age and from Cavite Province, were examined. The fibers were all stripped in the same manner with the nonserrated knife, those from each plant being mixed, sampled at random, and tested on the

Louis Shopper machine for comparative tensile strength. The results are given in Table 6.

TABLE 6.—*Comparative tensile strength of fibers obtained from normal and from diseased abacá plants affected by bunchy-top.*

Source of material.	Average tensile strength.*		Loss due to disease.	Remarks.
	Healthy.	Diseased.		
			<i>P. ct.</i>	
Amadeo.....	46.7	44.8	4.1	Young infection.
Indang.....	50.2	47.0	6.4	Do.
Mendez.....	48.4	43.8	9.5	Old infection.
Silang.....	47.8	41.4	13.3	Very old infection.
Do.....	54.5	48.6	10.6	Do.
Average.....	49.5	45.2		

* Average breaking strain in kilograms per gram meter of twenty samples.

While the data indicate that fiber from the diseased plants is somewhat weaker than that from healthy ones this cannot be ascribed to the deterioration of the fiber but, rather, to its failure to develop properly under the handicap of diseased conditions.

DETERIORATION UNDER COMMERCIAL METHODS OF STORAGE

In order to determine whether the temperature and moisture conditions in warehouses were suitable for rapid deterioration of stored fiber through fungous action, a comparative test was carried out as follows:

On February 4, 1924, a self-recording hygro-thermograph was placed among the bales of abacá fiber in the central warehouse of Smith, Bell and Company, one in that of Hanson and Orth Company, and another in the Bureau of Science, all located in Manila. Side by side with these hygro-thermographs were set out twelve cotton-plugged test tubes of sterile, wet abacá fiber (grade B), six of which were inoculated with *Aspergillus fumigatus*, and the other six left sterile as control.

Three observations were made during two months of incubation; the first on the twentieth day, the second on the fortieth day, and the third on the sixtieth day, testing on the machine the comparative tensile strength of all the fibers. The results obtained are given in Table 7.

As indicated in Table 7, the deterioration under warehouse conditions was essentially the same as in the laboratory exper-

iment carried on simultaneously at the Bureau of Science, which shows that commercial storage conditions at the time of the test were highly favorable to the development on wet fiber of one of the principal organisms concerned in the destruction of fiber.

TABLE 7.—*Effect of prolonged storage of damp mold-infected fiber under warehouse conditions.*

Location.	Relative humidity.			Relative temperature.			Incubation period.	Average tensile strength. ^a		Deterioration.
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.		Inoculated.	Control.	
	P. ct.	P. ct.	P. ct.	°C.	°C.	°C.	Days.			P. ct.
Smith, Bell and Company.....	58	92	75.7	22	35	30.4	20	38.7	41.4	6.5
							40	32.6	41.0	20.5
							60	16.2	40.2	59.7
Hanson and Orth Company.....	74	94	83.7	32	31	29.0	20	39.9	42.4	5.7
							40	32.3	41.0	21.1
							60	17.2	41.4	58.5
Bureau of Science.	64	82	73	24	30	27.2	20	37.6	40.4	7.1
							40	32.0	41.4	22.8
							60	18.8	40.7	53.8

^a Average breaking strain in kilograms per gram meter of twenty samples.

With regard to temperature, it is shown that the maximum that prevailed in the warehouses during the experiment ranged from 30 to 35° C., which, in itself, is not sufficiently high to cause disintegration of the fiber, but is suitable for the development of the cellulose-digesting organism responsible for the deterioration.

Manila hemp, like other vegetable fibers, is exposed to infection by various microorganisms from the time it is stripped from the leaf sheath of the abacá plant. When the fiber is kept in a place where favorable conditions for the growth of these microorganisms prevail, especially when it is not thoroughly dried (as is often the case in places where rain is more or less equally distributed throughout the year), it is likely to be destroyed in the course of a few weeks or months.

EFFECT OF HEAT ON ABACÁ FIBER

The effect of heat on the fiber was also determined, for undoubtedly abacá fiber, like cotton fiber, is likewise affected by this agent. As pointed out by Matthews,(5) the higher the

temperature to which cotton fiber is subjected, the greater the loss in weight and strength resulting from the process of dehydration of the cellulose, accompanied by structural disintegration of the fiber.

Fourteen uniform samples of abacá fiber (grade B), 0.5 meter long and weighing 2.5 grams each, were prepared in clean Petri dishes. The first group (1 and 2) was kept in the laboratory. All of the other groups were heated in an oven for an hour at the following temperatures: The second (3 and 4) at 60° C.; the third (5 and 6) at 80° C.; the fourth (7 and 8), at 100° C.; the fifth (9 and 10), sixth (11 and 12), seventh (13 and 14), and eighth (15 and 16) at 120° C. The last three were previously moistened with tap water representing 50, 100, and 200 per cent of their respective weights. Each sample was then taken out of the dish to permit air drying of the wet samples and restoral of the atmospheric moisture of the dried samples. The dried samples were observed to be hard and brittle, but they regained their moisture and softness on exposure to the air. Twenty samples were subsequently prepared from each group, the weight of each as air-dry fiber obtained, and the tensile strength as well as the stretch of each tested on the Louis Shopper machine. The results are given in Table 8.

It is apparent from Table 8 that abacá fiber, like cotton fiber, is affected by heat, the effect being noticeable in color, tensile strength, and stretch. The air-dry white sample, having about 11 to 12 per cent moisture when heated for three hours at 60° C. in an oven, did not show any marked difference in color

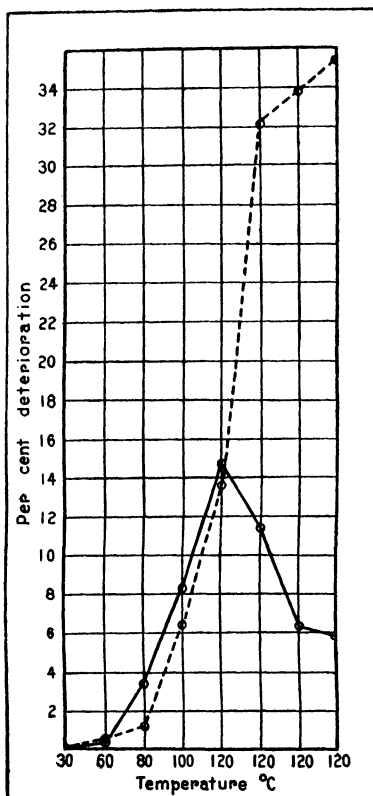


FIG. 2. Graphic illustration of the effect of heat on abacá fiber. Solid line, percentage of deterioration in tensile strength; broken line, percentage of deterioration in stretch.

and sustained no appreciable loss in strength and stretch; the change being very little even at 80° C. At 50 per cent moisture and 120° C., however, the changes became marked in both tensile strength and stretch, the latter increasing as the moisture was raised to 200 per cent. The color changed gradually to light buff and then warm buff as the temperature was raised from 80 to 120° C.

TABLE 8.—Effect of heat on tensile strength and on stretch of air-dry and wet fiber.

Samples.	Moisture when heated.	Temperature.	Color.	Average tensile strength.*	Average stretch.	Deterioration.	
						Strength.	Stretch.
	P. ct.	°C.			P. ct.	P. ct.	P. ct.
1 and 2.....	11 to 12	30	White.....	48.6	4.3	(b)	(b)
3 and 4.....	11 to 12	60	do.....	48.5	4.3	0.3	0.5
5 and 6.....	11 to 12	80	do.....	46.9	4.3	3.5	1.2
7 and 8.....	11 to 12	100	Light buff..	44.7	4.1	8.3	6.5
9 and 10.....	11 to 12	120	Buff.....	41.4	3.7	14.8	13.6
11 and 12.....	50	120	Warm buff..	43.0	2.9	11.4	32.1
13 and 14.....	100	120	do.....	45.5	2.9	6.4	33.9
15 and 16.....	200	120	do.....	45.7	2.8	5.9	35.4

* Average breaking strain in kilograms per gram meter of twenty samples.

^b Check.

EFFECT OF SALT WATER ON FIBER IN TRANSIT

It is believed by some that occasional wetting of fiber by salt water during transit may be directly responsible for its deteriorated condition on arrival at destination. To test the action of sea water, twelve test tubes of uniform sound abacá fiber (grade B) were prepared. Six of these were moistened with tap water and the rest with sea water before sterilization; four of each group were inoculated with *Aspergillus flavus*, leaving two tubes from each group as control. Observations were made after thirty days of incubation at room temperature (27 to 30° C.) and the comparative tensile strengths of the samples were derived by machine tests. The results are shown in Table 9.

It will be seen from Table 9 that the deterioration of the samples moistened with tap water was much greater than that of the samples moistened with salt water, the saline content of the solution acting as an inhibiting agent on the development of the mold used. Analyses made by Mr. A. S. Argüelles, chief of the division of soils and fertilizers, Bureau of Science, also

show that there is no appreciable difference in the chlorine content of deteriorated and sound fiber. Furthermore, it is a fact that not all deteriorated fiber samples have been wetted with sea water, and therefore deterioration cannot be attributed to the occasional wetting with sea water during transit.

TABLE 9.—*Relation of salt water to deterioration.*

Samples.	Average tensile strength.*		Deterioration.
	Inoculated.	Control.	
Moistened with tap water.....	20.1	45.9	<i>P. ct.</i> 56.3
Moistened with sea water.....	31.1	46.2	32.7
Difference in rate of deterioration.....			23.6

* Average breaking strain in kilograms per gram meter of twenty samples.

COMPARATIVE HISTOLOGICAL STUDIES OF SOUND AND UNSOUND FIBERS

Results of the foregoing experiments clearly demonstrate that deterioration of fiber may be due to the action of the cellulose-digesting organisms. Hence, comparative histological studies on both sound and damaged fibers were undertaken to determine the presence or absence of these organisms.

Sections of abacá fiber (grades D and J), about 5 millimeters long, from both sound and defective bales, were cut and treated separately with 10 per cent solution of hydrofluoric acid. After forty-eight hours the specimens were thoroughly washed in running water, dehydrated, cleared, embedded in paraffine, and sections made with a rotary microtome, 10 microns in thickness. From each of the samples twenty-five good slides were prepared and stained, using different kinds of stain, such as Hiltner's stain, Pianezze III B, etc., to bring out clearer differentiation between the organism and the fiber tissues.

As will be noted in Plates 4 and 5, the two fiber samples (sound and defective) differ greatly in two ways; namely, (a) bundles and tubes of the sound sample are of proper shape, whereas the defective sample is much disorganized; and (b) the sound sample shows no fungal infection, whereas the defective sample clearly demonstrates the presence of the fungus filaments embedded in the fiber tissues, marked X. It can be readily seen from this that the mold is devouring all parts of the fiber.

The viscose method, as employed by Cross and Bevan⁽²⁾ and modified by Thaysen and Bunker⁽⁶⁾ in their studies of cotton fiber, was then tried. Five-millimeter sections were cut from both sound and damaged fibers and soaked separately in a mixture of sodium hydrate and carbon bisulphide for from one to two hours, mounted on glass slides with cover slips, and then examined under the microscope.

Of one hundred slides of damaged abacá fiber of grades S1, I, J, and K from the warehouses of Smith, Bell and Company and of Hanson and Orth Company examined, about 80 per cent showed the presence of the cellulose-digesting organisms embedded in the fiber tissues (Plates 5 to 7). It is not surprising to note that some of the supposedly damaged fibers turned out negative when examined, in as much as in nature infection does not always occur throughout the entire length of the individual strand, but more often is limited to parts thereof which may happen to be exposed to the infecting organisms.

On the other hand, examination of normal fiber treated in the same way showed, in the majority of cases, no fungal hyphæ, either on or inside the fiber strands and individual ultimate fiber tubes; that is, of one hundred mounts examined, only five were positive and all the rest negative. Fresh, newly stripped fiber treated similarly showed, when examined, complete absence of any kind of infection.

The viscose method, as modified by Thaysen and Bunker,⁽⁶⁾ is useful in demonstrating the presence of fungal hyphæ in damaged fiber; however, further modification for the purposes of the present work seemed advisable. In determining whether or not molds or other microorganisms are present in the fiber tissues, I found that by soaking the fiber sections in carbon bisulphide for at least six hours (better still overnight) and then transferring them into a 5 per cent sodium hydrate solution, keeping them for another six hours, after which the sections are ready for mounting and examination under the microscope, at least two great advantages are gained; namely, (a) no yellow precipitate or air bubbles are formed in the fibers treated, and (b) the fiber elements are rendered semitransparent and distended but neither curled up nor split into ultimate fiber tubes. This leaves the microorganisms, if there be any at all, intact with their natural form, color, and position unchanged, rendering their detection easier.

MEANS OF CONTROLLING DETERIORATION

Complete elimination of the causal organisms is the surest way of stopping deterioration, but there are many practical difficulties in the way of accomplishing this. The molds that have been found responsible for the damage are by nature omnipresent, so that fiber is doubtless exposed to infection as soon as it is extracted from the leaf sheaths of the abacá plant. Bright and his collaborators⁽¹⁾ have tried various chemicals in connection with their study of mildew in cotton goods, as yet with comparatively meager results. Therefore, the only method of control at present recommended is the adoption of precautions that will reduce the liability to attack. Such precautions should, of course, deal mainly with the elimination of the factors favoring deterioration, which are discussed in the order of their importance in the following paragraphs.

Improper drying of fibers before baling and storage.—Of the different factors favoring deterioration of abacá fiber by the action of cellulose-digesting organisms, particularly the molds of the *Aspergillus* group, abundant moisture appears to be the most important. Therefore, great stress should be laid on the importance of drying all fiber properly before it is baled, stored, or shipped to its final destination. Properly dried fiber should not contain, on an average, more than 11 to 12 per cent of moisture, under Manila conditions. Even with this amount of moisture abacá fiber may lose 10 to 15 per cent of its tensile strength in sixty days by the action of the cellulose-digesting molds; and when the moisture content is raised to 100 per cent, the loss may be three or more times as great.

Keeping too long in storage.—Experiments have shown that moist, fine-grade fibers (grade B), when artificially inoculated with the cellulose-digesting organisms, sustain a loss of about 6 per cent in tensile strength after twenty days, about twenty per cent after forty days, and 55 per cent when incubation is extended to sixty days. For this reason, and because it is impossible to keep fiber from becoming infected with the omnipresent cellulose-digesting organisms, and since conditions obtaining in most of the warehouses are favorable for the development of these organisms, wet fiber should not be stored for long periods.

In the majority of cases speculation is at the root of any protracting of the period of storage and by this means losses

from deterioration are courted, not only from the action of the cellulose-digesting organisms, but also from other causes, such as rats, termites, and possibly fire.

Inadequate ventilation in the warehouses.—Experiments have shown that the cellulose-digesting organisms found to cause deterioration in fiber thrive best where humidity is high, and owing to inadequate ventilation this condition prevails in most of the warehouses where fiber is stored for a time before shipment abroad. Therefore, warehouses should be adequately ventilated.

Lack of care in handling fiber.—To minimize the chances of infection by the cellulose-digesting organisms, the need of proper care in handling fiber from the field to the factory cannot be too strongly emphasized. The sheds and warehouses where drying, sorting, baling, and other minor operations take place should be kept clean and dry, so as to keep the fiber uncontaminated. No refuse of any kind should be allowed to remain on the premises for even a day, but should be burned along with the waste fiber, for it constitutes a veritable hotbed of infection, and neglect in this respect will result in a rich crop of new cases of attack.

SUMMARY

1. This paper deals with abacá-fiber deterioration, numerous complaints against which have been received from fiber dealers of London since the latter part of 1920.

2. Deterioration is not confined to fibers from any one locality, although more cases of damage have been observed in those coming from the Bicol region.

3. Defective fiber is characterized by weakness, brittleness, a dull, dirty, dark color, and a musty odor, which is stronger in moist fiber than in dry.

4. The action of organisms belonging to the cellulose-digesting types like *Aspergillus flavus*, *A. fumigatus*, *A. glaucus*, *A. niger*, *A. wentii*, *Penicillium glaucum*, *Chaetomium elatum*, *C. funiculum*, *C. olivaceum*, and *C. olivaceum* var. *chartarum* will cause deterioration when conditions are favorable for their growth. Sometimes a species of *Alternaria* may be present and also cause damage.

5. There are at least five factors conducive to rapid deterioration of fiber by the cellulose-digesting molds; these are abundant moisture content, poor or partial cleaning, long storage of moist fiber, inadequate ventilation in the warehouses, and

lack of care in handling. Elimination of these factors would probably minimize deterioration due to molds to a point at which it would be practically nil.

ACKNOWLEDGMENTS

I am indebted to Dr. N. G. Teodoro, acting chief of the plant-pests control division, Bureau of Agriculture, for his valuable suggestions during the progress of the experiments; to Mr. A. S. Argüelles, chief of the division of soils and fertilizers, Bureau of Science, for the quantitative analysis of fibers for salt content; to Mr. M. Villaraza, of the fiber division, Bureau of Agriculture, for furnishing some of the materials used in the experiments; and to Messrs. E. Cortes and M. Ligaya, photographer and illustrator, respectively, of the Bureau of Science, for aid in the preparation of the illustrations.

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ILLUSTRATIONS

[All photographic illustrations were made by E. Cortes.]

PLATE 1

- FIG. 1. A "knot" of deteriorated abacá fiber (grade S1) from Camarines Norte. About $\frac{1}{4}$ natural size.
2. Portion of sample shown in fig. 1, showing discolored patches in detail. Note compacted strands which are so weak and brittle that they can be crushed into a powderlike mass in the hand. About $\frac{3}{8}$ natural size.

PLATE 2

- FIG. 1. Abacá fiber (grade S1) inoculated with *Aspergillus fumigatus* after moistening with sea water. The strands were broken into pieces when crushed in the hand. About $\frac{3}{4}$ natural size.
2. As in fig. 1, but not inoculated. Apparently it has not deteriorated, as the strands did not break into pieces when crushed in the hand. About $\frac{3}{4}$ natural size.

PLATE 3

- FIG. 1. Abacá fiber (grade S1) inoculated with *Aspergillus fumigatus* after moistening with tap water. Like that shown in Plate 2, fig. 1, it suffered from deterioration, and to a greater extent. About $\frac{3}{4}$ natural size.
2. As in fig. 1, but not inoculated. Like that shown in Plate 2, fig. 2. It did not sustain any loss in strength. About $\frac{3}{4}$ natural size.

PLATE 4

- FIG. 1. A transverse section of a single strand of sound abacá fiber (grade J) composed of five fiber bundles. Note parenchymatous cells surrounding them. Stained with Bismarck brown. $\times 125$.
2. A single bundle from the strand shown in fig. 1, highly magnified to show ultimate fiber tubes in detail. $\times 500$.

PLATE 5

- FIG. 1. A transverse section of a commercial strand of defective abacá fiber (grade J) composed of five fiber bundles, two of which (\times) are damaged and the rest (+) apparently good. Stained with Bismarck brown. $\times 125$.
2. A portion of strand shown in fig. 1, highly magnified to show much-disorganized cell tissues and fungus filaments bordering the cavity \times . $\times 500$.

PLATE 6

- FIG. 1. A commercial strand of defective abacá fiber (grade S1) treated with the viscose treatment. Note fungus threads (*Aspergillus flavus*) penetrating the entire strand. $\times 125$.
2. A portion of a commercial strand of defective abacá fiber (grade S1) treated with the viscose treatment; highly magnified to show in detail the mode of penetration of the fungus filaments (*Aspergillus fumigatus*). Note peculiar globular swellings and conidiophores. $\times 500$.

PLATE 7

- FIG. 1. Separate bundles of a strand of deteriorated abacá fiber (grade S1) after viscose treatment. Note penetration of the fungus filaments (*Aspergillus niger*) through the lumen (\times). $\times 125$.
2. Ultimate fiber tubes of defective abacá fiber (grade S1) after viscose treatment; highly magnified to show in detail the penetration of the fungal hyphæ (*Aspergillus fumigatus*) through the lumen of the uppermost and lowermost; the middle, which is out of focus, is free from infection. $\times 500$.

PLATE 8

All but fig. 5 are camera lucida drawings of *Aspergillus fumigatus* in different stages of development. (Drawings by Serrano.)

- FIG. 1. Two conidiophores. $\times 300$.
2. Spores. $\times 300$.
3. Spores, germinated. $\times 300$.
4. Hyphæ with peculiar globular swellings, and conidiophores. $\times 300$.
5. A portion of defective strand of abacá fiber (grade J) showing fructification of *Chaetomium funicolum*. $\times 125$.
6. A single immature ascus. $\times 350$.
7. A single mature ascus. $\times 350$.
8. Mature ascospores. $\times 350$.

PLATE 9

Three grades of abacá fiber (from left, B, J, and M), inoculated with different molds causing deterioration, and incubated for thirty days. Note more luxuriant growth of the molds, especially *Chaetomium*, on the coarser grades.

- FIG. 1. With *Aspergillus flavus*. $\times \frac{3}{4}$.
2. With *Aspergillus fumigatus*. $\times \frac{3}{4}$.
3. With *Aspergillus niger*. $\times \frac{3}{4}$.
4. With *Chaetomium funicolum*. $\times \frac{3}{4}$.

PLATE 10

[Water-color drawings by M. Ligaya.]

- FIG. 1. Normal abacá, Streaky No. 1, with a portion showing apricot orange to pansy purple color quite common on fibers from the outermost leaf sheaths.

- FIG. 2. Normal abacá, B, showing ivory white color with the characteristic luster of good fiber.
3. Deteriorated abacá, B, showing cartridge buff to tilleul buff color resulting from infection with molds.
 4. Deteriorated abacá, B, showing cream buff to vinaceous buff color with pale mouse gray patches resulting from infection with bacteria, yeast, and molds.

TEXT FIGURES

- FIG. 1. Showing graphically the rôles that age and poor or partial cleaning of fiber play in relation to deterioration. Left column, percentage of deterioration in strength; right column, percentage of deterioration in stretch.
2. Graphic illustration of the effect of heat on abacá fiber. Solid line, percentage of deterioration in tensile strength; broken line, percentage of deterioration in stretch.



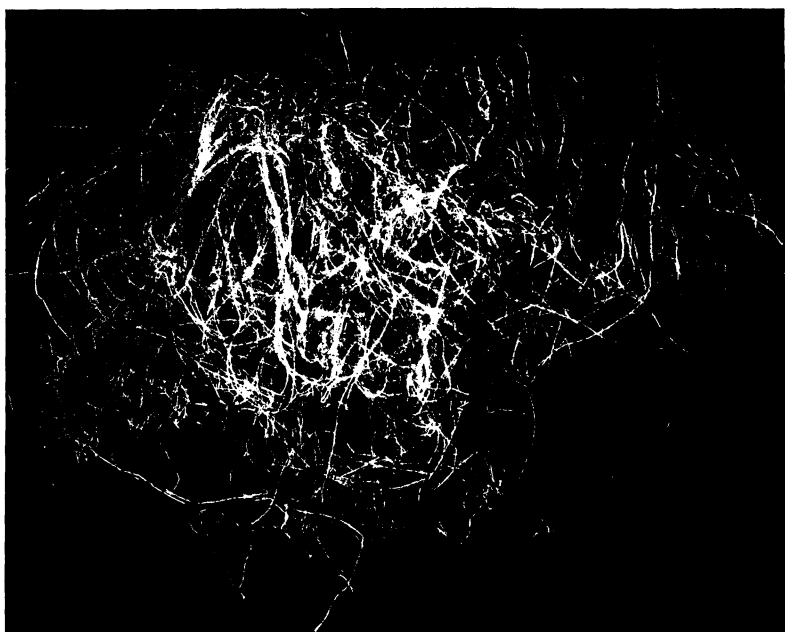
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PLATE 1.



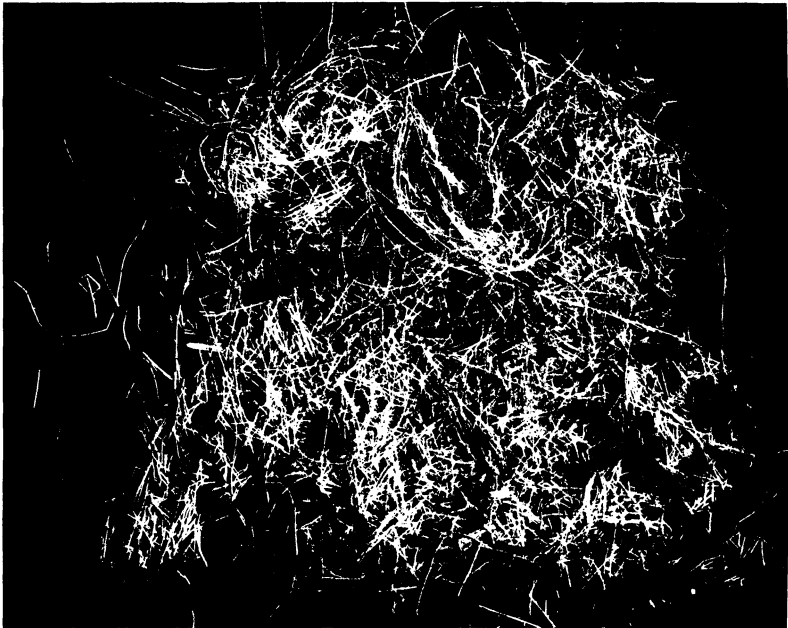


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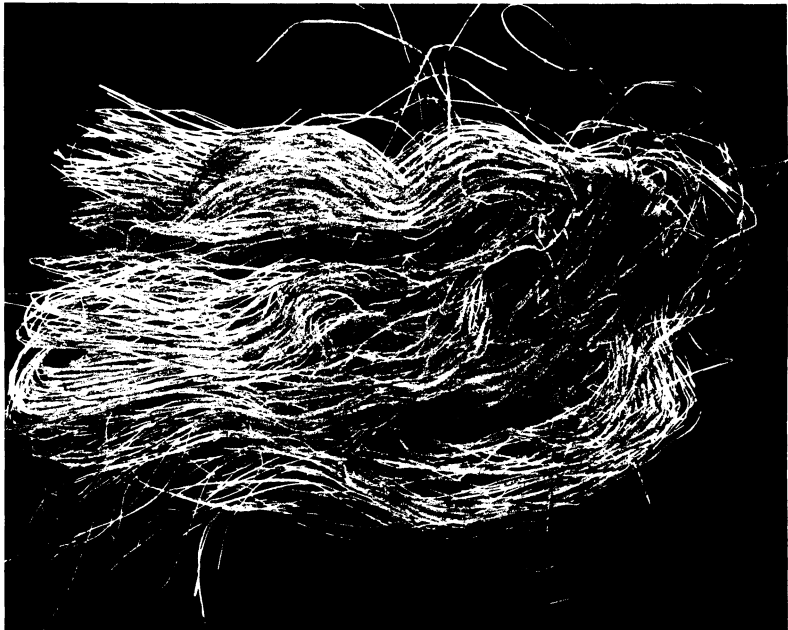


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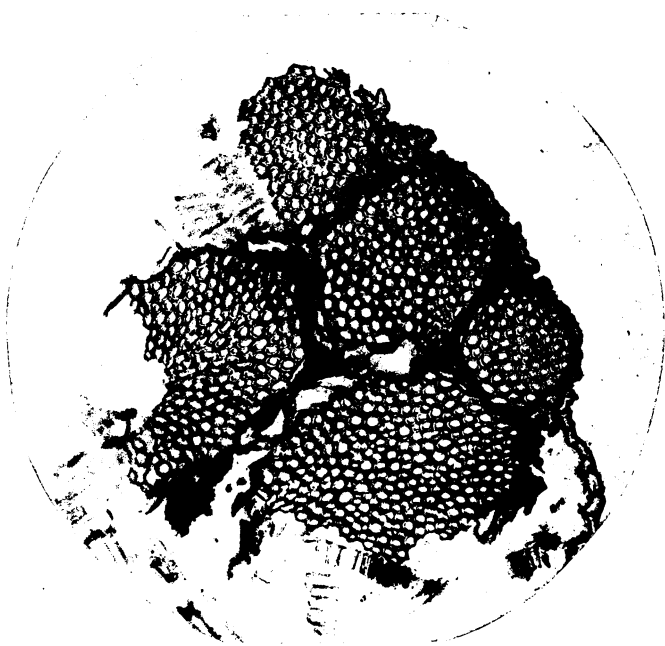


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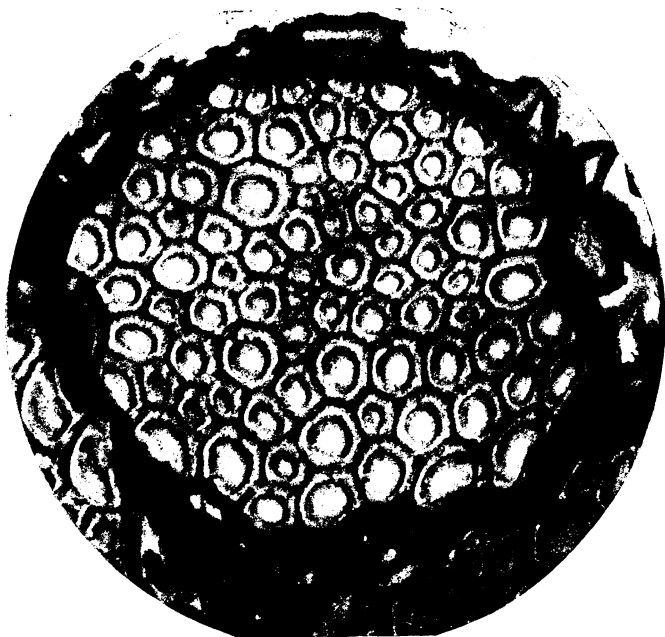


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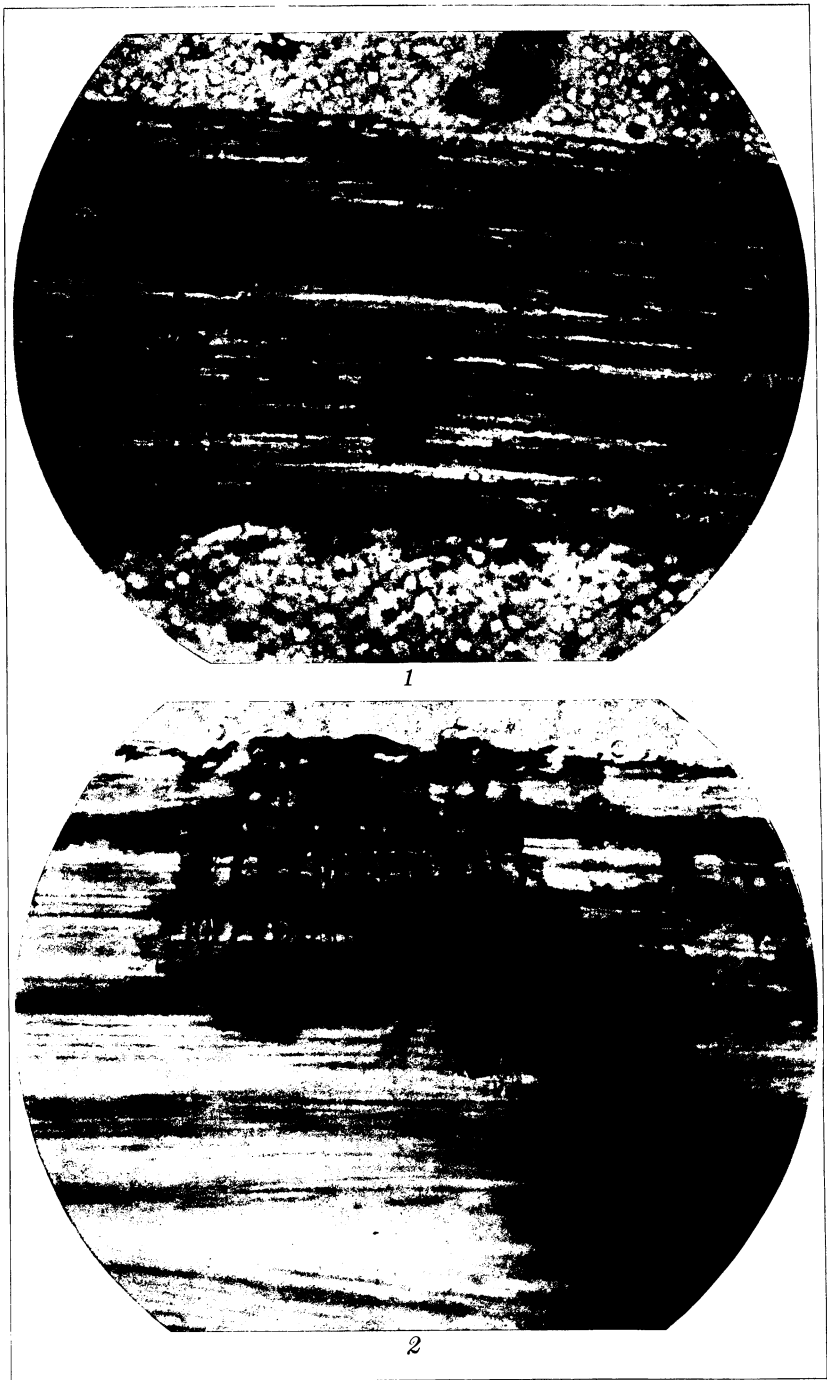


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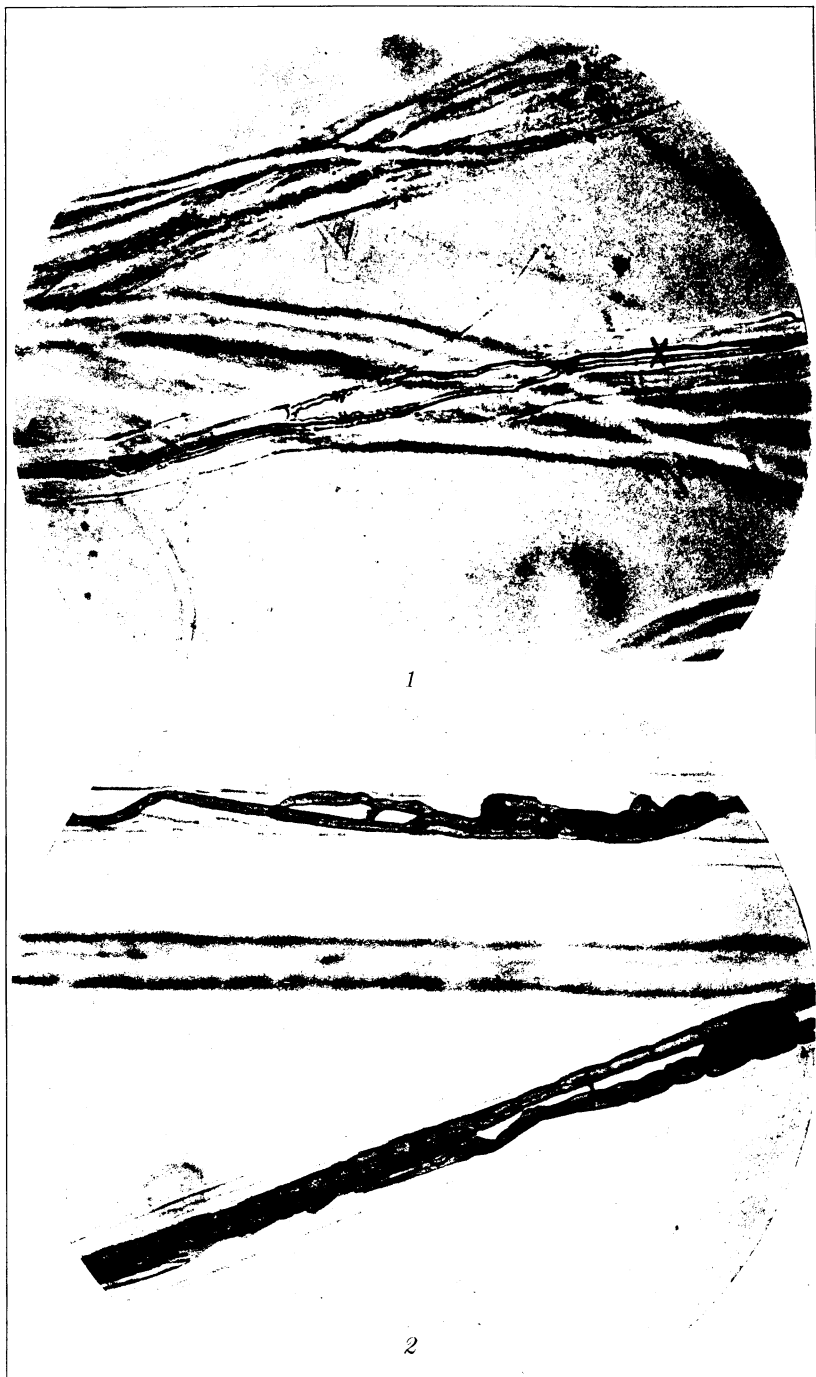


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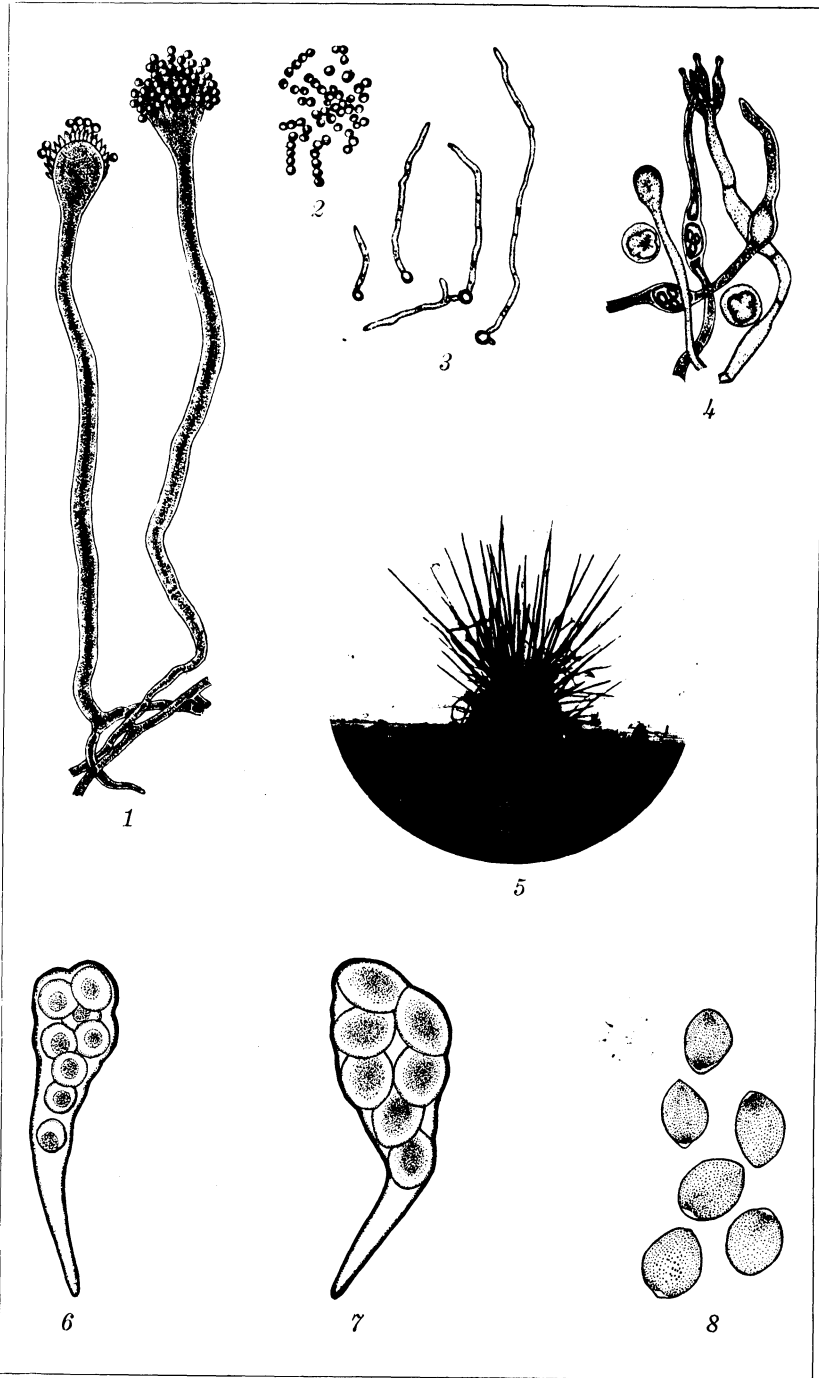


PLATE 8.





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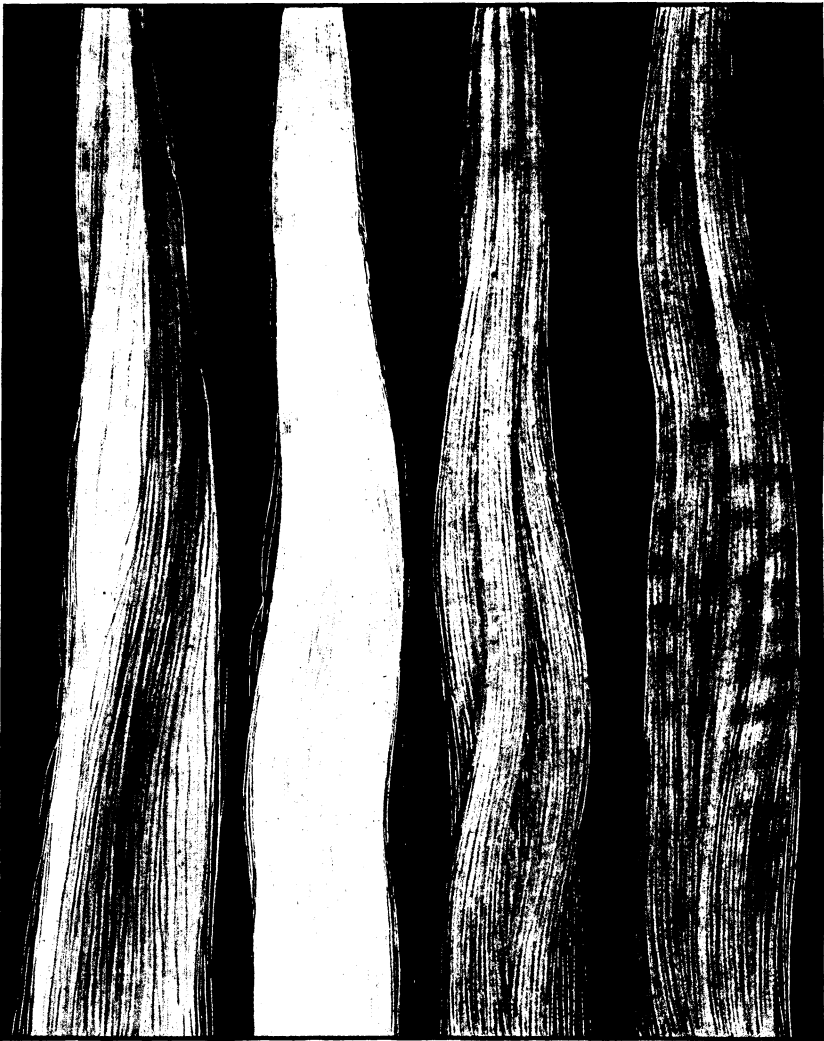


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PLATE 10.



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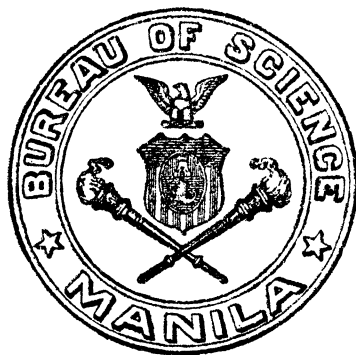
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THE PHILIPPINE JOURNAL OF SCIENCE

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FEBRUARY, 1927

No. 2

TROPICAL FUSARIA ¹

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Berlin-Dahlem, Germany*

SIX PLATES AND FORTY-SEVEN TEXT FIGURES

INTRODUCTION

The lack of knowledge in regard to species of *Fusarium* has made it almost impossible to state their actual distribution. An understanding of this condition is absolutely essential, from a pathological standpoint especially, for the determination of the protective or control measures to be instituted. If it is known, for instance, that disease-producing fusaria are not present in new lands to be planted to various crops, the question of preventing the introduction of the disease-producing strain is a vital one. On the other hand, wild, saprophytic soil strains, closely related to known pathogenic species, may be present in the soil, and it may be that the former can eventually, by a gradual process, develop the parasitic qualities necessary to produce disease. It is then the work of the plant breeder to develop new disease-resistant strains or varieties of plants to prevent infection by soil fungi.

While Reinking was conducting an investigation in regard to the distribution of the banana-wilt organism (*Fusarium*

¹ Published as a contribution from the Agricultural Research Department, United Fruit Company, Boston, Massachusetts.

cubense) in relation to banana culture, isolations of fusaria were made from the soil, and from banana and other plants, living and dead, in banana plantations and in the forest. Some five hundred fifty pure cultures of fusaria were obtained from all of these possible sources in banana lands of Honduras and Guatemala. After a detailed morphological study of these strains had been made, the number was finally reduced to some two hundred fifty, which still included a large number of identical species occurring on different hosts. These cultures were used as the basis for a joint investigation by us, working in the United States.² In these studies we were able to make comparisons with all the most-important strains of fusaria present in the United States and Europe. Forty-eight different fusaria were found to be present in the entire tropical collection. These comprise species of all but three sections of the subgenus *Fusarium*, and include perfect forms belonging to *Hypomyces*, *Calonectria*, *Gibberella*, and *Nectria*, of the Hypocreales. Fourteen fusaria were found to be new; namely, seven species, six varieties, and one form. (15)

The majority of the fungi described belong to sections that have parasitic species causing wilts, rots, and decays. For the greater part the parasitic nature of the species discussed still remains to be determined. (7) Whenever possible, the pathogenicity of each has been indicated. Investigations carried on in various parts of the world have already established the parasitic nature of species in some sections. In sections *Gibbosum* and *Roseum* are found species that cause fruit rots. The species in section *Liseola* (including *Fusarium moniliforme*, the cause of corn-mold disease) and related species are very abundant in the Tropics. The last-mentioned strains may quite possibly be found to produce disease in plants. No representatives of section *Discolor* were isolated in these studies, but it is known that some of these produce scab and blight of cereals grown in various parts of the world. Almost all of the known species of section *Elegans*, regarded as the cause of wilt disease, have been found in tropical soils. These were found in the main to be closely related, especially *F. cubense*, with the *oxysporum* group. Those isolated in the present investigations include *F. cubense* (banana wilt), *F. oxysporum* (potato wilt), *F. oxysporum* var. *nicotianae* (tobacco wilt) (see footnote 9,

* These studies were made during and after the *Fusarium* Conference held at Madison, Wisconsin, from June to August, 1924.

page 192), *F. aurantiacum* (wilt of Cucurbitaceæ), and *F. bulbigenum* (wilt of bulbs).⁽¹³⁾ The question whether or not these species collected in tropical soils may cause a wilt on their principal host remains to be proved. They may be wild, saprophytic soil forms of the proved parasites, requiring decades or even longer periods for gradual adaptation to cultivated plants of a tendency to assume semiparasitic habits. Some of the species in section *Martiella* are known to produce tuber, stem, and root rots of plants. The tropical collection made of fusaria of the *Martiella* section is significant, in that it shows that practically all known species are found in the soil. Heretofore these organisms have been isolated primarily from decaying plant material of various kinds. The morphological and physiological studies clearly prove that the various species retain their identity, even when isolated from the soil and not from a particular host plant.

By the differentiation of the species isolated in these studies it has been shown that some have a larger range of hosts and a greater geographical distribution than was formerly known. Other species apparently were determined to be more or less restricted to special hosts. The fact that a large number of the species of fusaria have been found in various parts of the world, including the Tropics, indicates that their distribution in general is world-wide. The geographical location need not cover the parasitic nature; it may be found that some species are parasitic in one country and not in another. The necessity for systematic inoculation studies by various investigators on different plants is evident.⁽⁷⁾

SOURCES AND METHODS OF ISOLATION

The organisms described were isolated from various sources with a view of obtaining a representative fusaria flora of banana plantations and of new forest lands to be planted with bananas. Isolations were made from wilt-diseased banana plants, from bananas with other types of disease, from banana trash, from other plants in banana plantations, in lands being prepared for banana plantations, or in virgin forests. Extensive soil isolations were conducted from soil in banana plantations and in the forest. Isolations were also made from the air to determine the prevalence of air-borne spores. The distribution of each of the various species is given under habitat in the general description.

After conducting an extensive study for determination of the best methods of isolation of soil fusaria and those growing on or within plant material, one general method was finally employed. Almost all fusaria grow well under rather high acid conditions; consequently, acid media were chiefly employed. Checks on the use of acid media were continually made by using nonacid media to determine whether or not certain uncommon types of fusaria were being overlooked. Most often ordinary acidified potato agar was used for isolation purposes.

The method of soil isolation adopted was to place a small amount of soil to be tested into a sterile Petri dish and add 1 to 2 cubic centimeters of a 2 per cent sterilized lactic acid solution. The plate was then poured with 10 cubic centimeters of potato agar and the soil particles separated by carefully rotating the dish. The acid inhibits all bacterial growth, but at the same time does not prevent the growth of any *Fusarium* that may be present. As soon as a fungus growth developed the plate was examined under the microscope by removing the cover of the Petri dish and placing the open dish on the microscope stage. Examination was made for fusaria spores and typical mycelial growth. An investigator soon becomes acquainted with the fusaria growth and can readily pick out the colonies. At this stage many other fungi are also present, especially various strains of molds. The colony of *Fusarium*, or as nearly a pure portion of it as possible, was then transferred to a tube of potato agar. The *Fusarium* will develop along with, but separately from, any other fungus that may be present. After a day or so of growth in the tube, the fusarial development and spores therefrom were transferred to a sterile water blank, shaken up thoroughly, and a poured dilution plate culture of one loopful of the same prepared. The *Fusarium* spores were in this way separated from any other spores that may have been present, and pure cultures of the various strains that developed were obtained. The original plates, with the soil, were always retained for later examination so that slow-growing strains of fusaria might not be overlooked. This method works splendidly with all fusaria that produce spores. Occasionally strains are found that primarily produce mycelium; these can generally be separated from other fungi by making transfers of the mycelium from portions of the growth that apparently is free from other organisms.

The isolation of fusaria from plant material was done by plating out a portion of the material, supposed to contain a

Fusarium, by means of a sterilized, flamed scalpel, on a plate of potato agar to which had been added 1 cubic centimeter of a 2 per cent sterilized lactic acid solution (Plate 4, fig. 5). The acid need not be added, but it inhibits all bacterial growth and at the same time does not prevent the development of the fusaria. As soon as a pure growth of *Fusarium* developed a portion was transferred to a tube of potato agar. If a pure culture could not be obtained directly from the resulting growth, the poured plate procedure for separation of fusaria from other fungi as discussed under the soil isolation method was employed.

MORPHOLOGICAL AND PHYSIOLOGICAL STUDIES

The morphological and physiological studies with the various strains were conducted according to the methods described in former papers. (1, 2, 9, 10, 11, 12, 14) Since the details regarding the criteria of the norm, the production of the norm, the use of various culture media, and the effect of other physiological factors have been fully discussed in these papers and especially summarized in one, (14) they need not be taken up here in detail. It might be well, however, to emphasize certain important points.

In the identification of species it is essential that a uniform method of procedure be followed. For proper determinations it is important to have different types of media in order to obtain the complete range of spore forms of a particular strain. It frequently may happen that somewhat different spore types are produced from different kinds of growth such as mycelium, pionnotes, or sporodochia. Sometimes, spores of particular species (*Fusarium cubense*) may have slenderer and longer spores in pionnotal masses than when produced from the mycelium or in older sporodochial masses. At least three good media are generally necessary for the production of the normal types. Oatmeal agar or potato agar, rice, and *Melilotus* or *Alnus* stems will generally give the requirements for a comprehensive study. These give, more or less, a range of natural conditions for growth of fusaria. Rice cultures in general will be found very helpful in grouping the fusaria into their respective sections according to the color reaction, although it must be remembered that color production is secondary to morphology. Ordinary potato-agar plate cultures (Plate 4, figs. 1 to 5) are frequently found useful in distinguishing between certain strains.

In studying the fungi under various climatic conditions, it has been found that the time required for production of normal spores varies. Under tropical influence normal spore production gen-

erally takes less time than in the temperate regions. The descriptions of the various fusaria as they grew on hard potato agar, potato-tuber plug, corn stalks, green bean pods, banana peel, and banana-fruit flesh were obtained from the fungus growth under tropical conditions. The range of temperature during these studies was between 17 and 31° C., with an average of approximately 25° C. The relative humidity ranged between 77 and 91, with an average of 84.5. The physiological studies on oatmeal agar, potato agar, plus 5 per cent glucose, rice, and *Melilotus* and *Alnus* stems were made in the Temperate Zone where the room temperature ranged from 21.5 to 25.5° C., with an average of 22.5° C. The cultures growing in the Tropics were kept in diffused light such as would normally be present in a screen-wire cabinet. Those grown in the temperate region were more fully exposed to the light, having been kept on tables under the general laboratory light conditions. No special precautions were taken to obtain nonsoluble glassware, even though it was known that a variation in color may be produced by chemicals, especially soluble alkalies, in the glass tubes. Minor changes in color character are not regarded as sufficient to modify the identification.

The morphological and physiological studies are summarized in the description of genera, species, varieties, and forms. A technical description is given of the fungus, the habitat, the growth characters on various media, and the measurements of conidia on different media and an average of these measurements. The measurements of conidia on different media, especially when the spores were taken from different sources, such as mycelium, pionnotes, or sporodochia, are significant in that they point out the possible differences that may arise within the same species when normal spores are produced under various conditions.⁽¹⁴⁾ The averages of these measurements give the average normal type, but need not necessarily clearly indicate the average size of different types as grown upon different media and under different sporulation conditions. For accurate determinations the average size of different types grown under their particular conditions is extremely important, and comparison should only be made of conidia produced under like circumstances.

In the study of the various species under a particular section it is found that one species gradually merges into the next higher in scale, starting from the small-spore types and running

up to the larger-spore types. A gradual evolution of the fusaria is here represented. This fact is often at first confusing in identifying fusaria; but, after a detailed morphological and physiological study has been conducted, it is found that there are certain distinct types that have been set apart to represent distinct species. Slight differences between different strains of the same species necessarily occur, ranging from the smallest type of spore to the largest within the species. This variation is only natural and what an investigator should expect. Because of this slight variation the temptation to classify new varieties is great and should be guarded against. The same difficulties are found in a systematic, taxonomic study of other members of the plant kingdom and merely represents a gradual evolution that has been taking place during the past hundreds of years. This evolution is clearly shown in the presentation of the various species under each section in the present paper, and is especially evident in section *Martiella*.

In giving the color descriptions of fungi on various media, the color standard and color nomenclature of Ridgway(8) were followed. Dried specimens and pure cultures of each strain of *Fusarium* have been placed in the herbarium of the mycological collection of the Bureau of Plant Industry, United States Department of Agriculture, for permanent preservation. Pure cultures of the fusaria new to science have been deposited with the Centraal Bureau voor Schimmelcultures, Baarn, Holland.

SYSTEMATIC ARRANGEMENT OF THE SPECIES OF FUSARIUM

The systematic arrangement of the species of *Fusarium* into sections, followed in the presentation, is according to the grouping of fusaria into sections as agreed upon at the general Fusarium Conference held at Madison, Wisconsin, June to August, 1924.(14) The species, varieties, and forms discussed under each section have been arranged according to the size of the spores, starting with the smaller type and ending with the larger type. All drawings in the text figures, unless otherwise stated, have been prepared to a uniform magnification of 1: 1000.

LIST OF FUSARIA

I. Section *Eupionnotes* Wollenweber.

Subsection *Chlamydospora* Wollenweber.

1. *Fusarium pusillum* Wollenweber.
2. *Fusarium dimerum* Penzig.

- III. Section *Sporotrichiella* Wollenweber.
3. *Fusarium chlamydosporum* Wollenweber and Reinking.
- V. Section *Arthrosporiella* Sherbakoff.
4. *Fusarium semitectum* Berkeley and Ravenel.
5. *Fusarium camptoceras* Wollenweber and Reinking.
6. *Fusarium incarnatum* (Robinson) Saccardo.
7. *Fusarium diversisporum* Sherbakoff.
8. *Fusarium anguioides* Sherbakoff.
- VI. Section *Gibbosum* Wollenweber.
9. *Fusarium bullatum* Sherbakoff var. *minus* Wollenweber and Reinking.
10. *Fusarium bullatum* Sherbakoff var. *brevius* Wollenweber and Reinking.
11. *Fusarium bullatum* Sherbakoff.
12. *Fusarium ossicolum* (Berkeley and Curtis) Saccardo.
13. *Fusarium falcatum* Appel and Wollenweber.
14. *Fusarium acuminatum* Ellis and Everhart emend. Wollenweber.
15. *Fusarium caudatum* Wollenweber.
16. *Fusarium longipes* Wollenweber and Reinking.
- VII. Section *Roseum* Wollenweber.
17. *Fusarium anthophilum* (A. Braun) Wollenweber.
- VIII. Section *Liseola* Wollenweber, Sherbakoff, Reinking, Johann, and Bailey.
18. *Fusarium moniliforme* Sheldon.
19. *Fusarium moniliforme* Sheldon var. *crumpens* Wollenweber and Reinking.
20. *Fusarium moniliforme* Sheldon var. *subglutinans* Wollenweber and Reinking.
21. *Fusarium moniliforme* Sheldon var. *maius* Wollenweber and Reinking.
22. *Fusarium neoceras* Wollenweber and Reinking.
- IX. Section *Lateritium* Wollenweber.
23. *Fusarium fructigenum* Fries var. *maius* Wollenweber forma 1 Wollenweber and Reinking.
- XI. Section *Spicarioides* (Wollenweber subsection) Wollenweber, Sherbakoff, Reinking, Johann, and Bailey.
24. *Fusarium decemcellulare* Brick.
- XII. Section *Saubinetii* Wollenweber.
25. *Fusarium macroceras* Wollenweber and Reinking.
- XIII. Section *Elegans* Wollenweber.
Subsection *Orthocera* Wollenweber.
26. *Fusarium bostrycoides* Wollenweber and Reinking.
27. *Fusarium orthoceras* Appel and Wollenweber.
28. *Fusarium orthoceras* Appel and Wollenweber var. *triseptatum* Wollenweber.

Subsection *Constrictum* Wollenweber.

- 29. *Fusarium bulbigenum* Cooke and Massee.
- 30. *Fusarium oxysporum* Schlechtendal.
- 31. *Fusarium oxysporum* Schlechtendal var. *nicotianae* Johnson.
- 32. *Fusarium cubense* Erwin F. Smith.
- 33. *Fusarium aurantiacum* (Link) Saccardo.
- 34. *Fusarium lutulatum* Sherbakoff.

XIV. Section *Martiella* Wollenweber (including *Pseudomartiella* Wollenweber.

- 35. *Fusarium solani* (Martius pro parte) Appel and Wollenweber var. *minus* Wollenweber.
- 36. *Fusarium solani* (Martius pro parte) Appel and Wollenweber var. *suffusum* Sherbakoff.
- 37. *Fusarium solani* (Martius pro parte) Appel and Wollenweber.
- 38. *Fusarium alluviale* Wollenweber and Reinking.
- 39. *Fusarium martii* Appel and Wollenweber var. *minus* Sherbakoff.
- 40. *Fusarium martii* Appel and Wollenweber var. *viride* Sherbakoff.
- 41. *Fusarium martii* Appel and Wollenweber.
- 42. *Fusarium viride* (Lechm.) Wollenweber.
- 43. *Fusarium radicola* Wollenweber.
- 44. *Fusarium striatum* Sherbakoff.
- 45. *Fusarium javanicum* Koorders.
- 46. *Fusarium theobromae* Appel and Strunk.
- 47. *Fusarium ensiforme* Wollenweber and Reinking.

Hypocreales:

Hypomyces (Fries).

- 48. *Hypomyces ipomoeae* (Halsted) Wollenweber.

DESCRIPTIONS OF GENERA, SECTIONS, SPECIES, VARIETIES, AND FORMS

Genus *FUSARIUM* Link

Fusarium LINK, Mag. Ges. Nat. Freunde 3 (1824) 10; SACCARDO, Syll. Fung. 4 (1886) 694; APPEL and WOLLENWEBER, Arb. aus. d. Kais. Biol. Anst. f. Land- u. Forstw. 8 (1910) 60-61; WOLLENWEBER, Phytopath. 3 (1913) 24-50; Ber. der Deut. Bot. Gesell. 31 (1913) 17-34; Journ. Agr. Research 2 (1914) 251-285; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 125; WOLLENWEBER, SHERBAKOFF, REINKING, JOHANN, and BAILEY, Journ. Agr. Research 30 (1925) 833-843.

Hyphomycetes and conidial stages of ascomycetes that have no black or pure gray color either in mycelium or in conidia; macroconidia acrogenous, typically septate, sickle-shaped, and not rounded at the ends; microconidia, chlamydospores, and sclerotia may be present.

I. Section EUPIONNOTES Wollenweber

Eupionnotes WOLLENWEBER, Phytopath. 3 (1913) 206 and 219; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 131; WOLLENWEBER, Ann. Myc. 15 (1917) 53; Ber. der Deut. Bot. Gesell. 35 (1918) 732.

Eupionnotes always present, spread out, dense, typical aërial mycelium absent, orange to salmon; conidia nearly cylindrical to sickle-shaped, moderately curved, slightly dorsiventral, apex ellipsoidal to conical, basis mostly apedicellate, septate, but septa frequently inconspicuous; chlamydospores 1-celled, 2-celled, in chains, rarely in heaps, or absent. Color type, orange to bright salmon.

Subsection CHLAMYDOSPORA Wollenweber

Chlamydospora WOLLENWEBER, Ann. Myc. 15 (1917) 53.

Differs from subsection *Aquaeductum* by the presence of chlamydospores. Definite sporodochia sometimes tubercular, and sclerotia may occur.

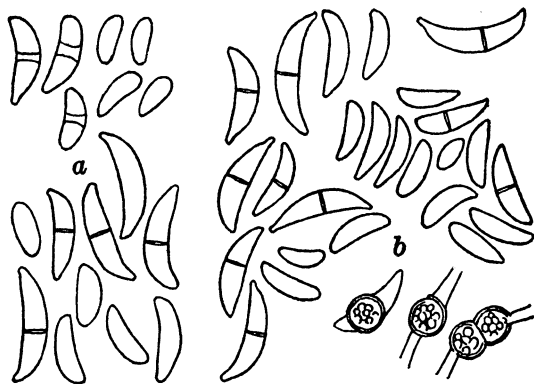


FIG. 1. *Fusarium pusillum* Wollenweber; a, conidia from pionnotes of 1-month-old hard potato-agar culture; b, *Fusarium dimerum* Penzig; conidia and chlamydospores of 2-month-old hard potato-agar culture.

FUSARIUM PUSILLUM Wollenweber. Text fig. 1, a.

Fusarium pusillum WOLLENWEBER, Fus. aut. del. Supplement No. 550 (1924).

Pionnotes yellow to golden, moderately spread out, in general similar to *F. dimerum*; conidia curved, 1-celled, 5 to 8 by 2.25 μ ; rarely 1-septate; chlamydospores may be present.

Habitat.—On sun-burned Congo banana fruit (*Musa sapientium* Linnæus). Panama. Central America (V. C. Dunlap 137, R 115).

Fusarium pusillum differs primarily from *F. dimerum* in that the majority of the conidia are 1-celled. Both species are

easily distinguished from all other fusaria by their characteristic, minute, 1-septate conidia. The fungus was not isolated by Reinking, but was obtained from Dr. V. C Dunlap in Panama.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 1.5 months old have no typical aërial mycelium, but have a coarse radiating mycelium in the agar. A pionnotal film is produced over the slant and is pinkish buff in young and cinnamon buff in 2-month-old cultures.

Oat agar.—No true aërial mycelium is present, but a dense matted stroma is developed over the slant. It is pale pinkish buff in young and old cultures. Light pinkish cinnamon and cinnamon pionnotes are produced.

Rice.—None to a scant aërial mycelium is produced. Pionnotes are formed over rice. In young cultures they are ochraceous salmon, and in older cultures rufous and cartridge buff at the base. The rice in older cultures may be mustard yellow.

Potato-tuber plug.—Pionnotal masses, with coarse and tufted mycelial strands, are present here and there over the cylinders. In younger cultures the growth is light buff and cinnamon rufous, while in older cultures it may be cinnamon buff or cinnamon rufous and leathery.

Melilotus stems.—Pinkish cinnamon pionnotes are produced in 2-month-old cultures over stem. Stroma erumpent, and tufts of pale pinkish buff mycelium are present here and there over the stem.

Green bean pod.—On cultures 1 to 2 months old, cinnamon and mikado brown pionnotes are formed over the bean pod.

MEASUREMENTS OF CONIDIA

Hard potato agar; cultures 1 month old; conidia from pionnotes:

Conidia—

0-septate, 90 per cent, 7 to 12 by 2.5 to 3.25 μ .

1-septate, 10 per cent.

FUSARIUM DIMERUM Penzig. Plate 1, fig. 1; text fig. 1, b.

Fusarium dimerum PENZIG, Michelia 2 (1882) 484; SACCARDO, Syll. Fung. 4 (1886) 704; LINDAU, Rab. Krypt. Fl. Pilze 9 (1910) 566; APPEL and WOLLENWEBER, Arb. Kais. Biol. Anst. Land- u. Forstw. 8 (1910) 37, text fig. 2; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 127; WOLLENWEBER, Ann. Myc. 15 (1917) 9-10; Ber. der Deutsch. Bot. Gesell. 35 (1918) 732.

Pionnotes pale cinnamon pink to orange pink, moderately spread out; tubercular sporodochia present, conidia curved,

approaching pedicellate, typically 1-septate, 13.5 by 2.75 (8 to 18 by 2 to 3.5) μ , often 0-septate, 12 by 2.75 (4.5 to 16 by 2 to 3.5) μ ; stroma erumpent, chlamydospores 3.5 to 6 μ in diameter, in mycelium and conidia.

Habitat.—On cut surface of decaying banana pseudostem (*Musa sapientium* Linnæus) and in the soil (*R* 154). Tela, Honduras, Central America (*Reinking* *R* 154).

GROWTH ON VARIOUS MEDIA

Hard potato agar.—No true aërial mycelium is produced. A radiating film of mycelium may be formed under the pionnotal mass on the agar. In pionnotes it is pale cinnamon pink in young cultures and vinaceous cinnamon in older cultures up to 2 months old. Pionnotes masses are present over the slant. They are pale pinkish buff on young cultures and vinaceous cinnamon and buff pink on older cultures.

Oat agar.—A dense, matted, pale pinkish buff stroma is formed over slant. Pionnotes are present over the slant and are light pinkish cinnamon and cinnamon.

Rice.—A mycelial mass is produced in with the pionnotes. It is waxy yellow in young cultures, pale cinnamon pink and cinnamon buff and leathery in older cultures. Under certain conditions orange pink or rufous may be produced. The rice in older cultures may be amber yellow or yellow ocher. The pionnotes growth is pale cinnamon pink on young cultures, salmon color and light ochraceous salmon on older cultures.

Potato-tuber plug.—The mycelium in with the pionnotes is cartridge buff in young cultures and pinkish cinnamon in older. A stroma erumpent, which is warm buff when young and bister and pinkish buff when older, is usually developed here and there over the cylinder. The pionnotes mass is generally vinaceous pink.

Melilotus stem.—The mycelium in with the pionnotes is pinkish buff. The stem in older cultures is covered with a stroma erumpent; the individual bodies measure from 0.5 to 3 mm in diameter. Light pinkish cinnamon and pinkish cinnamon pionnotes are developed over the stem. In older cultures brick red to reddish brown perithecialike sclerotial stromata, resembling a *Nectria*, may develop; the latter bodies are still under observation.

Green bean pod.—The mycelium in with the pionnotes is scant and pale pinkish cinnamon to cinnamon and light pink-

ish cinnamon. A pionnotes mass is produced over the bean and in older cultures is vinaceous cinnamon or orange cinnamon. A stroma erumpent, with individual bodies measuring 0.5 to 1 mm in diameter, develops over the bean in older cultures. It is cinnamon and snuff brown.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 10 days old; conidia from pionnotes:

Conidia—

0-septate, 100 per cent, 12 by 2.75 (4.5 to 16 by 2.25 to 3.5) μ .

Hard potato agar; culture 2 months old; conidia from pionnotes:

Conidia—

0-septate, 55 per cent.

1-septate, 45 per cent, 8 to 18 by 2 to 3.5 μ .

Morus stem, thirty days:

0-septate, 19 per cent.

1-septate, 81 per cent, 10 to 18 by 2 to 2.5 μ .

Green bean pod; culture 10 days old; conidia from pionnotes:

Conidia—

0-septate, 58 per cent, 9.5 by 3 (6.25 to 12 by 2.75 to 3.25) μ .

1-septate, 42 per cent, 13.5 by 3.25 (11 to 17 by 3 to 3.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

0-septate, 71 per cent, 12 by 2.75 μ .

1-septate, 29 per cent, 13.5 by 3 μ .

III. Section SPOROTRICHIELLA Wollenweber

Sporotrichiella LEWIS, Maine Agr. Exp. Sta. Bull. 219 (1913) 256;
SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915)
183; WOLLENWEBER and REINKING, Phytopath. 15 (1925) 156.

Conidia for the most part scattered in the aërial mycelium, pyriform to globose, unicellular, sporodochia absent in typical species, macroconidia few, fusiform or sickle-shaped, septate; chlamydospores and sclerotia may be present. Color type, rose color. Species, *F. poae* (Peck) Wollenweber; *F. sporotrichioides* Sherbakoff; *F. chlamydosporum* Wollenweber and Reinking.

FUSARIUM CHLAMYDOSPORUM Wollenweber and Reinking. Plate 1, fig. 2; text fig. 2.

Fusarium chlamydosporum WOLLENWEBER and REINKING, Phytopath.
15 (1925) 156.

Microconidia borne on irregularly branched conidiophores, ovoid, pyriform, mostly unicellular, 6 to 9 by 2.5 to 4 μ , rarely 1-septate, 11 to 16 by 3 to 3.5 μ ; macroconidia scattered, rare, sickle-shaped, 1- to 3-septate; 3-septate, 27 to 32 by 3.5 to 4 μ ; sporodochia absent; mycelium floccose, from rose to carmine, from sulphuric to dark brown; plectenchymic stroma sometimes

tubercular; chlamydospores globose to pear-shaped, rugose to spiny, ocherous, terminal or intercalary, 1- to 2-celled, in chains or clusters, 10 to 16 μ in diameter.

Fusarium chlamydosporum produces mostly microconidia of the *sporotrichum* type, a few sickle-shaped macroconidia, and an abundance of large chlamydospores that are characteristic for the species. The aërial mycelium develops swellings in some hyphæ that differ from chlamydospores in having no double wall (Plate 1, fig. 2). Such swellings are formed in *F. flocciferum* of the section *Discolor*, and in species of the section *Gibbosum*.

Habitat.—On the exterior of the pseudostem (*R* 38) and interior of a cut pseudostem of banana (*Musa sapientium* Linnaeus) and in the air and soil. Tela, Honduras, Central America (*Reinking R* 38).

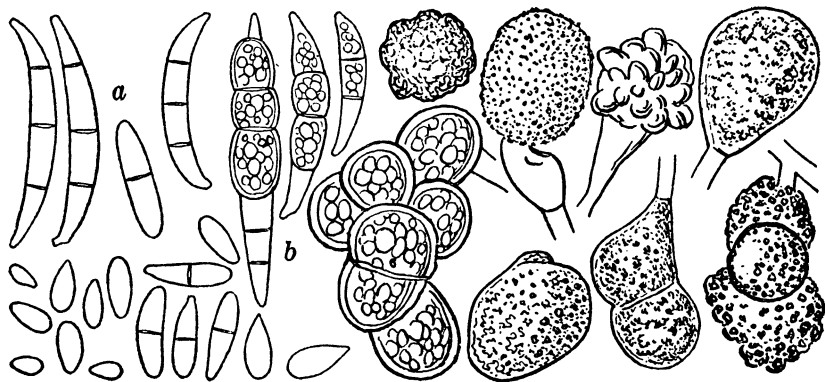


FIG. 2. *Fusarium chlamydosporum* Wollenweber and Reinking; a, conidia from mycelium of 2-month-old hard potato-agar culture; b, chlamydospores in conidia and mycelium of 2-month-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Young cultures 12 days old have a thick, dense, matted mass of mycelium that is cameo pink, thulite pink, spinel red, rosolane purple with spots of pinkish cinnamon on top and tawny olive and Saccardo's umber lower down. Older cultures, up to 2 months old, may be cameo pink, spinel red or cartridge buff, cinnamon buff, and cinnamon brown or buckthorn brown in places at base. The mycelium is dense and matted. The agar may be turned spinel red and Indian lake or Dresden brown. Bone brown thick stromatic masses may be produced at the base. On plate cultures the mycelial growth after one month is white and pale pinkish cinnamon over plate and

powdery in the center. The mycelium in the substratum is spinel red.

Potato-agar plate, 5 per cent dextrose.—The aërial mycelium is thick, dense, matted, and felty. It is cameo pink, spinel pink, spinel red to ferruginous in places. In the substratum it is brick red or Vandyke red.

Oat agar.—On oat agar 1 month old a thick, dense, matted, felty mass of mycelium is produced over slant. The main part is white and seashell pink with a little yellow ocher and buckthorn brown. The edges of the growth may be spinel red. The growth is powdery in places. Few mummy brown stromatic masses of mycelium may develop in spots.

Rice.—In young cultures, 2 to 3 weeks old, the mycelium is thick, matted, and felty and is white and rose pink above and yellow ocher around the rice below. The rice is colored dark vinaceous brown and seal brown. Cultures 2 months old have a leathery growth of mycelium that is cartridge buff or light ochraceous salmon on top with yellow ocher, Dresden brown, and mummy brown in places below. Jade green may appear in some cultures. Seal brown stromatic masses of mycelium may be produced in places.

Potato-tuber plug.—Three-week-old cultures have a dense, matted, white mycelium on top with pomegranate purple on the sides, especially where it touches the glass. Older cultures, up to 2.5 months old, are the same with an addition of Dresden brown and mummy brown in places. Dense stromatic masses that are mummy brown, often with pomegranate purple, may develop.

Melilotus stem.—In 1-month-old cultures a thick matted mass of mycelium is developed over the stem. It is pale pinkish buff, cinnamon buff, and clay color and powdery in places.

Alnus stem.—A dense mass of mycelium is developed on the top of the stem in cultures 1 month old. Scanty mycelium is produced on the side of the twig. The mycelium is spinel red and Indian lake.

Green bean pods.—In 3-week-old cultures the mycelial growth is dense and matted, white, cameo pink, thulite pink, and light rosolane purple. Older cultures have a dense mycelium that is cartridge buff, and pale pinkish cinnamon to cinnamon. Pinks and purples, as in the young cultures, may also be present.

Banana peel.—A dense matted mycelium that is white, cameo pink, thulite pink, and light rosolane purple is produced in 3-week-old cultures.

MEASUREMENTS OF CONIDIA

Hard potato agar; culture 2 months old; conidia from mycelium:

Conidia—

0-septate, 98 per cent, 7 by 3.25 (6 to 9 by 2.5 to 4) μ .

3-septate, 2 per cent, 29 by 4 (27 to 32 by 3.5 to 4.5) μ .

V. Section ARTHROSPORIELLA Sherbakoff

Arthrosporiella SHERBAKOFF, N. Y (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 161; WOLLENWEBER, Ber. der Deut. Bot. Gesell. 35 (1918) 733; WOLLENWEBER and REINKING, Phytopath. 15 (1925) 157.

Aërial mycelium abundant, whitish to flesh color; sporodochia and pionnotes typically absent; pionnotes present in few species; microconidia in aërial mycelium, spindle-shaped or lanceolate, apedicellate, 0- to 3-septate; macroconidia in masses. Isabella color or ochraceous, sickle-shaped, attenuate, often pedicellate, 3- to more-septate; chlamydospores typically intercalary, sclerotia rare, stroma ochraceous to chestnut brown or rosy, spread out, sometimes sclerotially erumpent.

FUSARIUM SEMITECTUM Berkeley and Ravenel. Plate 1, fig. 3; text fig. 3.

Fusarium semitectum BERKELEY and RAVENEL, Grevillea 3 (1875) 98; SACCARDI, Syll. Fung. 4 (1886) 718; WOLLENWEBER, Ann. Myc. 15 (1917) 11; WOLLENWEBER and REINKING, Phytopath. 15 (1925) 157.

Aërial mycelium white to flesh color or Isabella color, stroma plectenchymic, dark ochraceous, sometimes violet carmine,³ chlamydospores intercalary in mycelium and conidia, spiny at maturity; sporodochia absent; conidia scattered in aërial mycelium, spindle-shaped, lanceolate, slightly curved, apedicellate, appendicular, when smaller 0- to 2-septate, when larger 3- to 5- (6- or 7-) septate; 0-septate, 12 by 3 to 3.5 μ ; 1-septate, 11 to 21 by 2.5 to 4.5 μ ; 2-septate, 16 to 24 by 3.25 to 5 μ ; 3-septate, 18 to 40 by 3 to 5.5 μ ; 4-septate, 29 to 45 by 4 to 5.5 μ ; 5-septate, 36 to 52 by 4 to 5.5 μ ; 6- to 7-septate, 37 to 57 by 4.5 to 5.5 μ .

Habitat.—On dead floral parts at the end of banana fruit (R 50), on anther and pollen grains of banana, on dead floral parts of banana on the ground, in the interior of a cut pseudostem of banana, and on diseased banana fruit (*Musa sapientium* Linnæus), at blossom end rot of tomato fruit (*Lycopersicum esculentum* Miller), and in the air as air-borne spores. Tela, Honduras, Central America (Reinking R 50).

³ Other strains of doubtless the same species, isolated from bananas of the European market by Wollenweber, as a rule do not produce a violet carmine color of the stroma.

Fusarium semitectum is generally widespread throughout banana plantations, growing on the dead floral remains at the end of the individual banana fruits and decaying banana fruit and floral parts on the ground. Its pathogenicity has not been established.

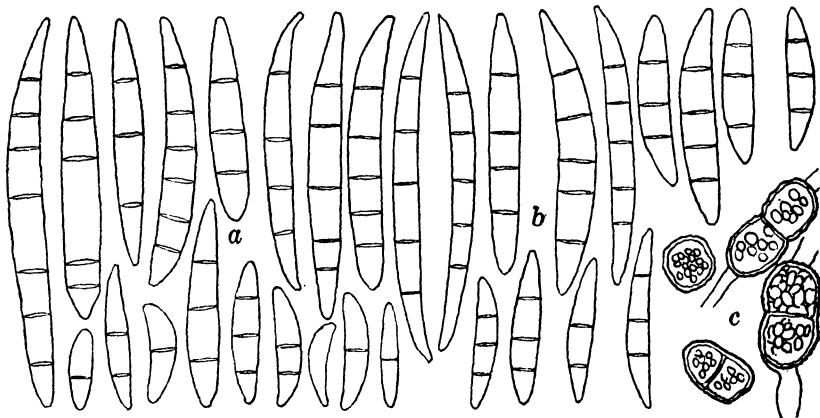


FIG. 3. *Fusarium semitectum* Berkeley and Ravenel; a, conidia from mycelium of 8-day-old rice culture; b, conidia from mycelium of 1-month-old hard potato-agar culture; c, chlamydospores from 14-day-old water culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—On young cultures a median dense, matted and, in places, tufted mycelium develops over slant. It is cartridge buff, pale pinkish buff, and pale pinkish cinnamon with cinnamon buff at the base. A buckthorn brown ring may be produced at the base. On the agar, under the main mass of mycelium, the growth is salmon buff or cinnamon buff. The agar may be dark vinaceous brown at the base of the slant. Older cultures up to 3 months of age have a dense matted mycelium that is light buff, buckthorn brown, or snuff brown. On potato-agar plates 2 months old a thin white mycelial growth, which may be distinctly zonate, is produced.

Potato-agar plate, 5 per cent dextrose.—On cultures 1 month old a scant aërial mycelium is produced, and the mycelium in the substratum is sayal brown and zonate.

Rice.—In cultures 3 weeks old the mycelium is matted and felty, but not extremely thick. It is warm buff and light pinkish cinnamon above, chestnut brown and carob brown on the sides, and buckthorn brown and mummy brown below. The rice turns Vandyke red and Indian lake in places. In older cultures,

up to 2 months of age, the mycelium is leathery and Natal brown on the glass above with bone brown on rice and wood brown or Natal brown lower down. A salmon buff coloration may be present at the base.

Potato-tuber plug.—On cultures 3 weeks old the mycelium is dense, matted, and felty with a light buff, pale ochraceous buff, honey yellow, or Isabella color. Clay color may be produced where the mycelium touches the glass. Cultures 2 to 3 months old are dense, felty, matted, and leathery in places. The mycelium is cartridge buff, pinkish buff, cinnamon brown, or buckthorn brown and Dresden brown in places.

Melilotus stem.—On cultures 2 months old a pale pinkish buff, matted, felty mycelium is produced over the stem.

Green bean pod.—In young cultures 3 weeks old, the mycelium is dense, matted, and felty over the bean with a color that is pale pinkish cinnamon, pale pinkish buff, pinkish buff, and sometimes with cinnamon buff in places. Under the mass of mycelium on the bean the growth may be cinnamon or sayal brown. Older cultures have a thin, matted mycelium that is pinkish buff, cinnamon buff, and clay color with sayal brown in places.

Banana peel.—A scant to median thin, pale pinkish buff, and pinkish buff or cinnamon buff mycelium is produced over the banana peel.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; cultures 1 month old; conidia from mycelium:

Conidia—

- 0-septate, 51 per cent, 8.5 by 2.75 (4 to 16 by 2.25 to 3.25) μ .
- 1-septate, 4 per cent, 15.5 by 3.5 (10 to 19 by 2.75 to 4) μ .
- 2-septate, 4 per cent, 20 by 4 (15 to 25 by 3.25 to 4.5) μ .
- 3-septate, 33 per cent, 30 by 4 (15 to 45 by 3.25 to 5) μ .
- 4-septate, 6 per cent, 40 by 4 (27 to 47 by 3.5 to 5) μ .
- 5-septate, 1 per cent, 35 by 4.5 (23 to 46 by 4.5 to 5.5) μ .
- 6-septate, 1 per cent, 33 by 4.5 μ .

Green bean pod; cultures 10 days old; conidia from mycelium:

Conidia—

- 0-septate, 1 per cent, 9.5 by 3.5 (4 to 13 by 2.25 to 3.5) μ .
- 1-septate, 10 per cent, 14 by 4 (12 to 19 by 3 to 4.5) μ .
- 2-septate, 5 per cent, 20 by 3.75 (13 to 24 by 3 to 5.5) μ .
- 3-septate, 42 per cent, 26 by 4.25 (18 to 40 by 3.5 to 6.25) μ .
- 4-septate, 22 per cent, 38 by 4.75 (25 to 45 by 3.5 to 6.25) μ .
- 5-septate, 12 per cent, 37 by 4.75 (26 to 50 by 4 to 6.25) μ .
- 6-septate, 7 per cent, 38 by 5.5 (30 to 53 by 4.5 to 6.25) μ .
- 7-septate, 1 per cent, 42 by 5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 0-septate, 25 per cent, 9 by 3.25 (4 to 16 by 2.25 to 3.5) μ .
 1-septate, 7 per cent, 15 by 3.75 (10 to 19 by 2.75 to 4.5) μ .
 2-septate, 5 per cent, 20 by 3.75 (13 to 25 by 3 to 5.5) μ .
 3-septate, 33 per cent, 28 by 4 (15 to 45 by 3.25 to 6.25) μ .
 4-septate, 14 per cent, 39 by 4.5 (25 to 47 by 3.5 to 6.25) μ .
 5-septate, 6 per cent, 42 by 4.5 (23 to 50 by 4 to 6.25) μ .
 6-septate, 4 per cent, 36 by 5 (30 to 53 by 4.5 to 6.25) μ .
 7-septate, 1 per cent, 42 by 5 μ .

FUSARIUM CAMPTOCERAS Wollenweber and Reinking. Plate 1, fig. 4; text fig. 4.

Fusarium camptoceras WOLLENWEBER and REINKING, *Phytopath.* 15 (1925) 158.

Aërial mycelium white to flesh to blood red or Isabella color; stroma dark ochraceous, sometimes flesh color; chlamydospores intercalary in mycelium and conidia; sporodochia absent; co-

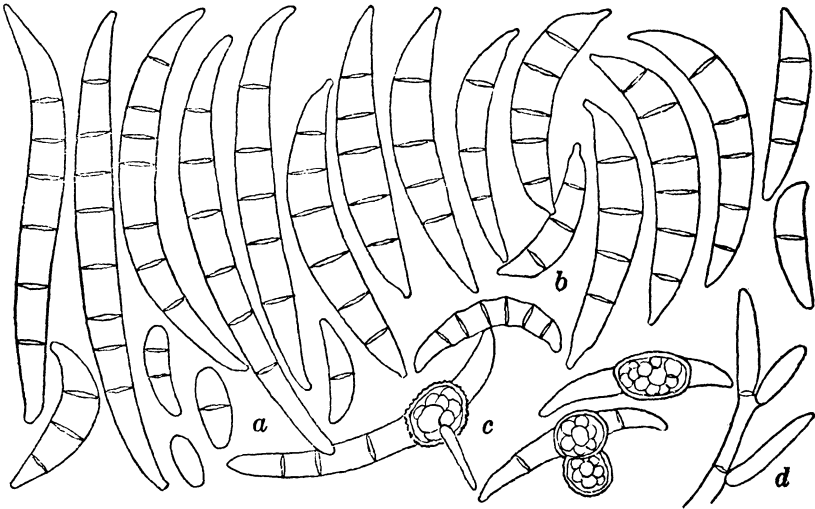


FIG. 4. *Fusarium camptoceras* Wollenweber and Reinking; a, conidia, long narrow type, from mycelium of 8-day-old hard potato-agar culture; b, conidia, short broad type, from mycelium of 15-day-old hard potato-agar culture; c, chlamydospores from 15-day-old water culture; d, conidiophore from 12-day-old hard potato-agar culture.

nidia scattered in the aërial mycelium; sickle-shaped, slightly pointed at ends, more or less constricted at top end, rounded or conical at base, sometimes apedicellate, however, appendicular, smaller conidia 0- to 2-septate, larger conidia 3- to 5- (6- or 7-) septate; 0-septate, 7 to 12 by 2.5 to 3.5 μ ; 1-septate, 11 to 18 by 3 to 4 μ ; 2-septate, 14 to 26 by 3.5 to 5 μ ; 3-septate, 17 to 32 by 3.5 to 5.5 μ ; 4-septate, 22 to 40 by 3.5 to 6 μ ; 5-septate, 29 to 52 by 4.5 to 6 μ ; 6-septate, 25 to 58 by 4.5 to 5.5 μ ; 7-septate, 31 to 51 by 4 to 5.5 μ .

Habitat.—On rotted fruit of banana (*Musa sapientium* Linnæus) and cacao (*Theobroma cacao* Linnæus) (*R* 78) and in the soil. Tela, Honduras, Central America (*Reinking R* 78).

Differs from *F. semitectum* by somewhat higher septation and more-curved conidia, and by the production of ox-blood red in the stroma.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—On 2-week-old agar, a medium thick, matted mycelium, sometimes in concentric rings, of thick and thin mycelium is formed over the slant. The mycelium is at first cartridge buff and chamois and later turns light buff and pinkish buff with a sayal brown ring at the base. Older cultures have a matted, felty, thick growth of light buff, pinkish buff, and buckthorn brown mycelium. Under the mycelial mass on the agar the growth may be cinnamon. On potato-agar plates 2 months old a pale pinkish cinnamon, scant, and zonate mycelium is present over the plate.

Potato-agar plate, 5 per cent dextrose.—The aërial mycelium on plates 1 month old is zonate and radiate, short woolly to felty, and pale pinkish buff and cinnamon buff. The mycelium in the substratum is auburn.

Oat agar.—Oat-agar cultures 1 month old have a thick felty mycelium over the slant. The mycelium is pale pinkish cinnamon and tawny olive in patches below. The agar is turned sayal brown.

Rice.—Young cultures 3 weeks old have a dense, felty, matted mycelium that is light buff and buckthorn brown above, and mummy brown, Natal brown, or bone black below. The rice may be changed to garnet red. Older cultures may be somewhat leathery and are cartridge buff and cinnamon on top, bone brown on sides, and pinkish buff and light pinkish cinnamon and sometimes orange vinaceous below. The rice is often ox-blood red and garnet brown.

Potato-tuber plug.—Young cultures 3 weeks old have a dense, felty mass of mycelium over the potato. The mycelium is mainly light buff with clay color, tawny olive, and black where it touches the glass. Older cultures are felty and matted, chiefly light buff with buckthorn brown, cinnamon brown, Dresden brown, mummy brown, and blackish brown(3) in places. The mycelium may be leathery below.

Melilotus stem.—Cultures 1 month old have a pale pinkish cinnamon, medium dense, and felty mycelial growth over the stem.

Alnus stem.—A scant, pale pinkish cinnamon growth of mycelium is produced over the stem after one month's growth.

Green bean pod.—On cultures 10 days old a white and pinkish buff, felty, matted mycelium is produced. Older cultures are cartridge buff, cream buff with pale pinkish buff, and pinkish cinnamon in places.

Banana peel.—A medium dense, matted, pale pinkish buff mycelium is produced over the banana peel on 2-month-old cultures.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; cultures 1 month old; conidia from mycelium:

Conidia—

- 0-septate, 4 per cent, 10 by 3.25 (7 to 12 by 2.25 to 3.5) μ .
- 1-septate, 7 per cent, 14 by 3.5 (13 to 15 by 3.5 to 4) μ .
- 2-septate, 5 per cent, 19 by 4 (14 to 19 by 3.5 to 4.5) μ .
- 3-septate, 20 per cent, 22 by 4 (17 to 24 by 3.5 to 4.5) μ .
- 4-septate, 9 per cent, 27 by 4.5 (22 to 28 by 4.5 to 5.25) μ .
- 5-septate, 18 per cent, 37 by 5.25 (32 to 37 by 5 to 6) μ .
- 6-septate, 33 per cent, 34 by 4.5 (25 to 41 by 4.5) μ .
- 7-septate, 4 per cent, 46 by 4.75 (46 by 4.5 to 5) μ .
- 8-septate, rare, 65 by 5 μ .

Green bean pod; cultures 1 month old; conidia from mycelium:

Conidia—

- 0-septate, rare, 8 by 2.75 μ .
- 1-septate, 1 per cent, 11 by 3.5 μ .
- 2-septate, 8 per cent, 17 by 4 μ .
- 3-septate, 40 per cent, 23 by 4.75 (18 to 28 by 3.5 to 5.5) μ .
- 4-septate, 32 per cent, 31 by 4.5 (26 to 35 by 3.5 to 5.5) μ .
- 5-septate, 13 per cent, 32 by 5 (32 to 33 by 4.5 to 5.5) μ .
- 6-septate, 3 per cent, 33 by 5 (31 to 37 by 4.5 to 5.5) μ .
- 7-septate, 3 per cent, 40 by 4.25 (36 to 44 by 4 to 4.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 30 per cent, 23 by 4.25 (17 to 28 by 3.5 to 5.5) μ .
- 4-septate, 21 per cent, 29 by 4.5 (22 to 35 by 3.5 to 5.5) μ .
- 5-septate, 15 per cent, 35 by 5 (32 to 37 by 4.5 to 6) μ .
- 6-septate, 18 per cent, 34 by 4.75 (25 to 41 by 4.5 to 5.5) μ .
- 7-septate, 3 per cent, 43 by 4.5 (36 to 46 by 4 to 5) μ .

FUSARIUM INCARNATUM (Robinson) Saccardo. Text fig. 5.

Fusarium incarnatum SACCARDO, *Michelia* 2 (1881) 296; Syll. Fung. 4 (1886) 712; WOLLENWEBER, *Ann. Myc.* 15 (1917) 11; *Journ. Agr. Research* 2 (1914) 258.

Mycelium floccose lanate, brownish white to salmon color; sporodochia and pionnotes absent; conidia formed into a salmon-color powder, subnormal conidia unicellular or septate, rounded at the ends, seldom pointed, normal conidia show characters of

the section *Discolor*, but are less curved and have mostly a conical, seldom a pedicellate base; slender conidia, occasionally found, should not be confused with the section *Elegans* (*F. orthoceras*); 3-septate conidia, 20 to 25 by 3.5 to 4.5 μ ; 5-septate, 30 to 50 by 3.75 to 5 μ , may be predominant; 10-septate conidia occur more rarely; conidiophore mostly irregularly branched, sometimes with slightly verticillate ramifications; chlamydospores 1- to 2-celled, formed, intercalated from hyphæ and from conidia; olive brown plectenchymata of remarkable longevity produced.

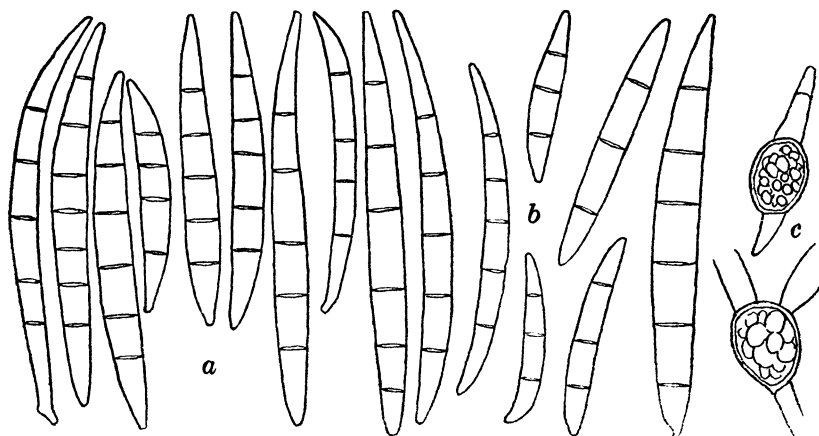


FIG. 5. *Fusarium incarnatum* (Robinson) Saccardo; a, conidia from mycelium of 1-month-old oatmeal-agar culture; b, conidia from mycelium of 1-month-old hard potato-agar culture; c, chlamydospores from 1-month-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

The fungus resembles *Fusarium trichothecioides* Wollenweber in general appearance. *Fusarium semitectum* is closely related, but may have smaller conidia and on the average fewer septa.

Habitat.—On petiole of decaying undetermined leaf on ground (*R* 89) and in the soil. Trujillo, Honduras, Central America (*Reinking R* 89).

Hard potato agar.—Young cultures 4 days old have a medium dense, cottony, and somewhat matted, white growth. As the cultures grow older the mycelium becomes denser and turns mainly pale pinkish buff with possibly tawny olive below. When fruiting a more or less powdery, salmon buff growth is produced. Older cultures, up to 3 months old, are cartridge buff above and pinkish cinnamon, dense, and matted below. A buckthorn brown ring may be produced at the base. Concentric

rings of a dense and thin mycelium may also be formed. On potato-agar plates 2 months old a pale pinkish buff, thin, felty mass of mycelium is developed.

Oat agar.—A pale pinkish cinnamon, thick, dense, felty mass of mycelium that is tawny olive at the base and sides of the slant is present in cultures 1 month old.

Rice.—On cultures 20 days old the mycelium on top is white, light buff, and pale cinnamon pink, lower down it is buckthorn brown and zinc orange on the glass. On the sides of the rice it may also be flesh color or cameo pink. The rice itself turns shrimp pink and often mustard yellow on top. Cultures 2 months old have a light ochraceous buff and ochraceous salmon, leathery mycelium on top, warm buff and light buff mycelium at sides, and ochraceous orange or pale grayish vinaceous in the rice below. Clove brown or Dresden brown patches may appear in places. Powdery spore masses are ochraceous salmon.

Potato-tuber plug.—Cultures 1 month old have a white, pinkish buff and tawny olive, dense, matted, felty mycelium over the potato. Older cultures are the same with a change to cinnamon and sayal brown in places.

Melilotus stem.—Cultures 1 month old have a pale pinkish buff, medium dense, and matted mycelium over the stem.

Alnus stem.—Same as on *Melilotus* stem.

Green bean pod.—Cultures 1 to 2 months old have a pale pinkish buff, pinkish buff, or a pale pinkish cinnamon, light pinkish cinnamon to cinnamon, dense, thick, matted, and felty mycelium over bean. Plectenchymic masses that are warm buff may be produced in places.

Banana peel.—Cultures 26 days old have a scant white and orange cinnamon mycelial growth.

Mature corn stalk.—A scant, white mycelial growth is produced in young and old cultures.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 1 month old; conidia from mycelium:

Conidia—

- 0-septate, 2 per cent, 12 by 3 (10 to 14 by 2.75 to 3.25) μ .
- 1-septate, 14 per cent, 21 by 3 (18 to 27 by 2.75 to 3.5) μ .
- 2-septate, 5 per cent, 25 by 3.25 μ .
- 3-septate, 55 per cent, 27 by 3.5 (21 to 32 by 3.25 to 4) μ .
- 4-septate, 7 per cent, 34 by 4.25 (32 to 36 by 4 to 4.5) μ .
- 5-septate, 17 per cent, 39 by 4.5 (33 to 42 by 4.5) μ .
- 6-septate, rare, 39 by 4 μ .

Not in best high cultures.

Oat agar; cultures 1 month old; conidia from mycelium:

Conidia—

3-septate, 30 per cent.

4-septate, 28 per cent.

5-septate, 42 per cent.

Green bean pod; culture 12 days old; conidia from mycelium:

Conidia—

0-septate, 1 per cent, 8 by 2.25 μ .

1-septate, 5 per cent, 14 by 2.5 (9 to 17 by 2 to 2.75) μ .

2-septate, 2 per cent, 18 by 3 (18 to 19 by 2.75 to 3.25) μ .

3-septate, 25 per cent, 19 by 3.5 (17 to 23 by 3 to 4) μ .

4-septate, 10 per cent, 34 by 4 (30 to 41 by 3.5 to 4.5) μ .

5-septate, 41 per cent, 40 by 4.25 (35 to 44 by 4 to 5) μ .

6-septate, 8 per cent, 42 by 4.5 (37 to 48 by 4 to 5) μ .

7-septate, 2 per cent, 48 by 4.5 μ .

8-septate, 3 per cent, 56 by 5.25 (55 to 59 by 5 to 5.5) μ .

9-septate, 3 per cent, 61 by 4.5 (56 to 67 by 4.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 37 per cent, 23 by 3.5 (17 to 32 by 3 to 4) μ .

4-septate, 15 per cent, 34 by 4 (21 to 41 by 3.5 to 4.5) μ .

5-septate, 37 per cent, 39 by 4.25 (33 to 44 by 4 to 5) μ .

FUSARIUM DIVERSISPORUM Sherbakoff. Text fig. 6.

Fusarium diversisporum SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 161; WOLLENWEBER, Ann. Myc. 15 (1917) 11.

Sherbakoff's diagnosis, with slight changes, is as follows:

Aërial mycelium typically well developed, medium fine, white; typical sporodochia absent, pionnotes on mycelial sheet; conidia formed in a light pink cinnamon, powdery mass; conidia short, spindle-shaped (average 3-septate, 28 by 4.3 μ) to sickle-shaped, 5-septate, 48.5 by 3.63 (41 to 61 by 2.9 to 4.4) μ , 6- to 9-septate conidia common, 60 to 100 by 4.7 to 5.2 μ , slightly curved to straight and anguiform, apically pointed, sometimes distinctly but not prominently pedicellate; chlamydospores may be present, intercalary in mycelium and in conidia. *Fusarium diversisporum* produces a pionnotes and represents a border-line species to the section *Roseum*.

Habitat.—On tassel of corn and on brown spots in living leaves of corn (*Zea mays* Linnæus) (*R* 75). Tela, Honduras, Central America (*Reinking* *R* 75). Wollenweber has found also ocherous globose sclerotia in a strain of *F. diversisporum*, isolated from *Carica papaya* from the Philippines.*

* Cf. Fus. Aut. del. 118.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—On cultures 11 days old is developed a dense mycelial mass that is mainly pale pinkish buff with salmon and salmon buff where masses of conidia are produced, and tawny olive at the base. In older cultures the mycelium becomes flattened and changes from pale pinkish buff or light pinkish cinnamon with buckthorn brown at the base of the slant to cream buff and pinkish buff. On potato-agar plates 2 months old there is a scant aërial mycelium which is pale pinkish buff.

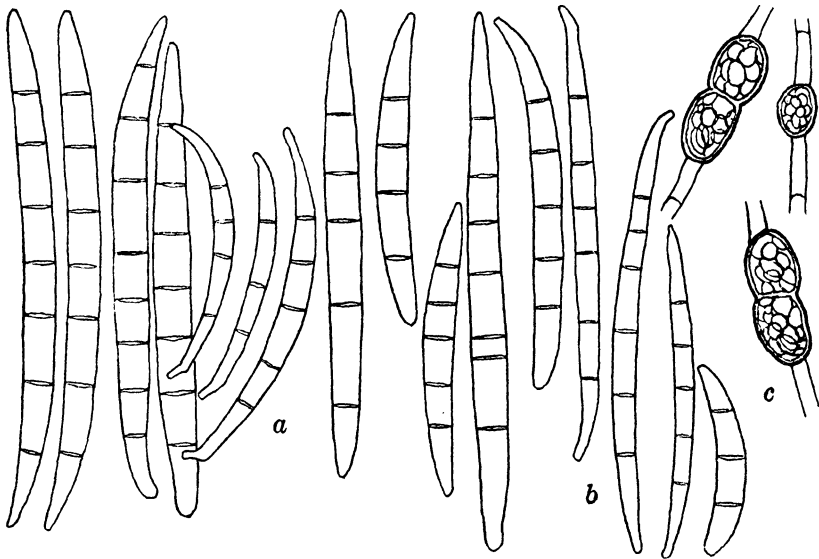


FIG. 6. *Fusarium diversisporum* Sherbakoff; a, conidia, large, slightly curved to spindle-shaped, nonpedicellate and small, spindle-shaped, pedicellate, from mycelium of 10-day-old hard potato-agar culture; b, conidia, slightly curved to straight and anguiform, from pionnotes of 10-day-old oatmeal-agar culture; c, chlamydospores from 14-day-old water culture.

Potato-agar plate, 5 per cent dextrose.—A pale pinkish buff, scant aërial mycelium is produced on cultures 1 month old. The substratum is changed to light pinkish cinnamon.

Oat agar.—Cultures 1 month old have a medium thick and matted mycelium that is pale pinkish buff, usually with a mummy brown ring at the base and sides of the slant.

Rice.—Cultures 20 days old have a white, pale pinkish buff, buckthorn brown, and cinnamon brown, medium dense, and matted mass of mycelium over the rice. The mycelium may be leathery below. Older cultures, up to 2 months old, have a cartridge buff, pinkish buff, light pinkish cinnamon and cin-

namon brown, leathery mass over the rice. Where spores are produced in abundance in pionnotes, the culture is light ochraceous salmon.

Potato-tuber plug.—Cultures 1 month old have a dense matted growth of mycelium that is cream buff and cinnamon buff above and olive ocher and mummy brown below. Cultures 2 months old have a dense, matted, cinnamon brown mycelium above and buckthorn brown and mummy brown, leathery below. Pinkish buff and salmon buff, more or less powdery spore masses develop in places on the mycelium. Mummy brown plectenchymic bodies may also be formed.

Melilotus stem.—Cultures 1 month old have a pale pinkish buff, medium thin, and matted aërial mycelium over the stem.

Alnus stem.—Cultures 1 month old have a pale pinkish buff and pinkish buff, powdery, medium, scant mycelium in places on the stem.

Green bean pod.—Young and old cultures have a pale pinkish buff, pinkish buff, and cinnamon buff, dense, felty, and matted mycelium.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; cultures 22 days old; conidia from powdery masses in mycelium:

Conidia—

0-septate, rare.

1-septate, 1 per cent, 17 by 3 (14 to 21 by 2.25 to 3.5) μ .

2-septate, 1 per cent, 17 by 2.5 (15 to 18 by 2.25) μ .

3-septate, 25 per cent, 29 by 3.25 (19 to 36 by 2.75 to 4) μ .

4-septate, 20 per cent, 34 by 3.75 (29 to 44 by 3.25 to 4) μ .

5-septate, 50 per cent, 41 by 4.25 (32 to 61 by 3.5 to 4.45) μ .

6-septate, 2 per cent, 41 by 5 (40 to 64 by 5 to 5.5) μ .

7-septate, 1 per cent, 60 by 5 (56 to 72 by 4.5 to 5.5) μ .

8-septate, rare, 65 by 5 μ .

Oat agar; culture 2 weeks old; conidia from pionnotes:

Conidia—

3-septate, 6 per cent.

4-septate, 3 per cent.

5-septate, 82 per cent, 55 by 3 (44 to 66 by 2.75 to 3) μ .

6-septate, 9 per cent.

Rice; culture 2 months old; conidia from pionnotes:

Conidia—

1-septate, 6 per cent.

2-septate, 1 per cent.

3-septate, 14 per cent.

4-septate, 4 per cent.

5-septate, 61 per cent.

6-septate, 9 per cent.

7-septate, 5 per cent.

Green bean pod; culture 21 days old; conidia from mycelium:

Conidia—

- 0-septate, 2 per cent, 11 by 3.25 (7 to 15 by 2.25 to 3.5) μ .
- 1-septate, 6 per cent, 17 by 3 (14 to 23 by 2.25 to 3.25) μ .
- 2-septate, 4 per cent, 20 by 3.25 (15 to 26 by 2.75 to 3.5) μ .
- 3-septate, 45 per cent, 28 by 3.75 (16 to 41 by 3.25 to 4.5) μ .
- 4-septate, 14 per cent, 34 by 4 (24 to 47 by 3.5 to 5) μ .
- 5-septate, 28 per cent, 40 by 4 (32 to 50 by 3.5 to 5.5) μ .
- 6-septate, 1 per cent, 59 by 6 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 23 per cent, 29 by 3.5 (16 to 41 by 2.75 to 4.5) μ .
- 4-septate, 10 per cent, 34 by 3.75 (24 to 47 by 3.25 to 5) μ .
- 5-septate, 55 per cent, 45 by 3.75 (32 to 66 by 2.75 to 5) μ .

FUSARIUM ANGUIOIDES Sherbakoff. Text fig. 7.

Fusarium anguioides SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta.
Memoir No. 6 (1915) 169.

Sherbakoff's description of the species is as follows:

Conidia of diverse types, ranging from arthrosporial (short, spindle-shaped with more or less rounded ends, 0- to 3-septate) to typically slightly curved or nearly straight and anguiform, 1- to 15-septate, 1- and 3-septate conidia typical for the first form

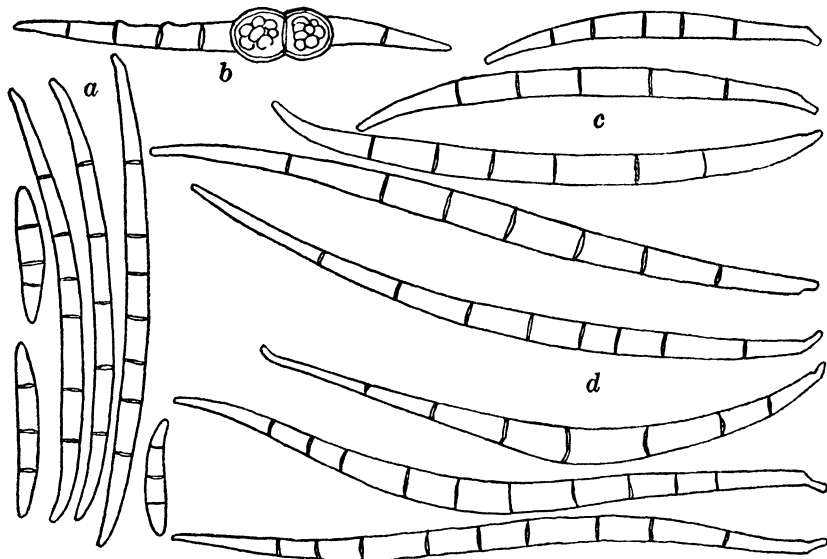


FIG. 7. *Fusarium anguioides* Sherbakoff; a, conidia, small, narrow, slightly curved, from mycelium of 1-month-old potato-tuber plug culture; b, chlamydospores in conidium from 1-month-old rice culture; c, conidia, large and broad, nearly straight, from pionnotes of 18-day-old oatmeal agar culture; d, conidia, large and broad, irregular, from pionnotes of 1-month-old rice culture.

and measuring 27 by 4.4 (20 to 38 by 3.9 to 5.3) μ ; for the other form the conidia commonly measuring as follows:

5-septate, 51 by 4.2 (47 to 68 by 3.9 to 4.6) μ .

6- and 7-septate, 76 by 4.6 (65 to 86 by 4.2 to 5.2) μ .

8- and 9-septate, 89 by 4.86 (80 to 102 by 4.3 to 5.8) μ .

Color of conidia in pseudopionnotal layer on glucose potato agar, ranging from light pinkish cinnamon to cinnamon; arthrosporial conidia of common occurrence on aërial mycelium, but often the latter, especially on different agar, nearly absent, when a thin spore layer (pseudopionnotes) is produced for which anguiform conidia are typical.

We observed in addition intercalary chlamydospores in mycelium and conidia; no sporodochia were observed, but pionnotes developed. The term pseudopionnotes is not used in the present paper, as it is included in that of pionnotes. The main part of the spores developed from the mycelium. *Fusarium anguioides* represents a border-line strain to the section *Roseum* and resembles in some characters *F. anthophilum* (A. Braun) Wollenweber, from which it differs in higher septation of conidia and by the presence of chlamydospores.

Habitat.—On dead leaf petiole of undetermined plant on ground. Trujillo, Honduras, Central America (*Reinking* 90). On dried pods of pigeon pea (*Cajanus indicus* Spreng) and in soil. Tela, Honduras, Central America (*Reinking*). On plant débris. Jamaica (*C. G. Hansford* 17, *R* 236).

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 10 days old usually have a dense, matted mycelium that is chiefly pale pinkish buff and tawny olive at the base. Salmon and salmon buff spore masses, pionnotes, are developed over the agar. Cultures from 1 to 3 months old have a dense, matted, felty mycelium that is cartridge buff, light buff, pinkish buff, and cinnamon buff with buckthorn brown at the base of the slant.

Potato-agar plate, 5 per cent dextrose.—One-month-old plates have a scant aërial mycelium that is pale pinkish buff. The substratum is colored russet. A pionnotes is produced.

Oat agar.—One-month-old cultures have a scant aërial, powdery mycelium that is pale cinnamon pink and light vinaceous cinnamon. A stromatic mass of mycelium is produced over the slant with a pionnotes developed thereon.

Rice.—Twenty-day-old cultures have a white, pale pinkish buff and pale pinkish cinnamon, medium dense, matted my-

celium with spots of ochraceous tawny, Dresden brown, and mummy brown over rice. The mycelium may be leathery in places. Older cultures, up to 2 months of age, have a dense, matted mycelium that is cartridge buff, pinkish buff, and light pinkish cinnamon with sayal brown, tawny olive, and snuff brown in places. A pinkish buff pionnotes may be present.

Potato-tuber plug.—Eighteen-day-old cultures have a chamois and salmon buff, dense, matted mycelium. A salmon buff pionnotes may be present. Older cultures, between 1 and 2 months old, are felty and light buff on top with cinnamon brown, vinaceous brown, and Natal brown below. The mycelial mass may be leathery below. A vinaceous buff pionnotes may be produced.

Melilotus stem.—Scant pale cinnamon pink aërial mycelium is produced in 1-month-old cultures.

Alnus stem.—Scant, pale cinnamon pink aërial mycelium is produced in 1-month-old cultures. A light vinaceous cinnamon pionnotes develops at the outer edges of the twig.

Green bean pod.—Cultures 1 month old have a medium scant, white, cartridge buff, and pale pinkish buff mycelium. Salmon pionnotal masses may be produced.

Banana peel.—Cultures 1 month old have a medium dense, white mycelium.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Oat agar; culture 18 days old; conidia from pionnotes:

Conidia—

- 0-septate.
- 1-septate, 2 per cent.
- 2-septate, 1 per cent.
- 3-septate, 27 per cent.
- 4-septate, 13 per cent.
- 5-septate, 42 per cent, 58 by 3.5 (45 to 72 by 3.25 to 4) μ .
- 6-septate, 11 per cent.
- 7-septate, 2 per cent (70 to 93 by 3.5 to 4) μ .
- 8-septate, 2 per cent.

Hard potato agar; culture 8 days old; conidia from mycelium:

Conidia—

- 0-septate.
 - 1-septate.
 - 2-septate.
 - 3-septate, 5 per cent, 35 by 2.75 (30 to 40 by 2.5 to 3) μ .
 - 4-septate, 9 per cent, 35 by 2.75 (30 to 40 by 2.5 to 3) μ .
 - 5-septate, 50 per cent, 46 by 3.5 (36 to 62 by 3.5) μ .
 - 6-septate, 11 per cent
 - 7-septate, 18 per cent
 - 8-septate, 6 per cent
 - 9-septate, 1 per cent
- (61 to 90 by 3 to 4) μ .

Potato-tuber plug; culture 1 month old; conidia from mycelium:

Conidia:

0-septate.

1-septate, 1 per cent, 19 by 3 (15 to 23 by 1.75 to 3.5) μ .

2-septate, 3 per cent, 24 by 3 (18 to 30 by 2.75 to 3.5) μ .

3-septate, 33 per cent, 29 by 3 (17 to 41 by 2.5 to 3.5) μ .

4-septate, 9 per cent, 36 by 3 (32 to 42 by 2.75 to 3.5) μ .

5-septate, 48 per cent, 49 by 3 (40 to 58 by 2.5 to 3.5) μ .

6-septate, 3 per cent, 32 by 3.25 μ .

7-septate, 2 per cent, 75 by 3.25 (60 to 90 by 3) μ .

8-septate, 1 per cent.

Green bean pod; culture 17 days old; conidia from mycelium:

Conidia—

0-septate, 2 per cent, 19 by 3 μ .

1-septate, 13 per cent, 18 by 2.5 (14 to 23 by 2.25 to 2.75) μ .

2-septate, 2 per cent.

3-septate, 26 per cent, 31 by 4 (27 to 37 by 3.5 to 4.5) μ .

4-septate, 11 per cent, 41 by 4.75 (40 to 43 by 4.5 to 5.25) μ .

5-septate, 46 per cent, 48 by 5 (38 to 58 by 4 to 6) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 19 per cent, 32 by 3.25 (17 to 41 by 2.5 to 4.5) μ .

4-septate, 11 per cent, 37 by 3.5 (30 to 43 by 2.5 to 5.25) μ .

5-septate, 46 per cent, 50 by 3.75 (36 to 72 by 2.5 to 6) μ .

6- to 9-septate (60 to 93 by 3 to 4) μ .

The average measurements obtained were slightly narrower than those given by Sherbakoff. This is considered to be due to the fact that under certain conditions the conidia are broader than usual, as shown in the measurements on green bean pods. Neither were such long nor as many-septate spores obtained as described by Sherbakoff. It is believed that the cultures here described would under suitable conditions produce longer and larger conidia.

IV. Section GIBBOSUM Wollenweber

Gibbosum WOLLENWEBER, *Phytopath.* 3 (1913) 31; SHERBAKOFF, N. Y. (Cornell) *Agr. Exp. Sta. Memoir No. 6* (1915) 133; WOLLENWEBER, *Ber. der Deutsch. Bot. Gesell.* 35 (1918) 734.

Mycelium from white to brown; conidial mass typically pale buff to cinnamon and sepia; conidia in sporodochia and piono-
notes, pale ochraceous to orange, dorsiventral sickle-shaped, elliptical with parabolic or hyperbolic curves, attenuate at both ends, pedicellate; sometimes smaller conidia in aërial mycelium, comma-shaped, 0- to 3-septate, rounded at both ends or slightly constricted, apedicellate; chlamydospores intercalary in mycelium and conidia; sclerotia rare, sometimes dark blue; stroma plectenchymic, ochraceous, chestnut brown, or carmine.

FUSARIUM BULLATUM Sherbakoff var. **MINUS** Wollenweber and Reinking. Plate 1, fig. 5; text fig. 8.

Fusarium bullatum minus WOLLENWEBER and REINKING, *Phytopath.* 15 (1925) 159.

Differs from the type species by smaller conidia; conidia in sporodochia or in pionnotes, pedicellate, mostly 3-septate, 27 to 35 by 3 to 4 μ ; seldom 4- or 5-septate; 5-septate, 33 to 42 by 3.5 to 4.5 μ ; conidia in aërial mycelium sometimes sub-normal apedicellate, 3- (1- to 5-) septate.

Habitat.—On plant debris. Jamaica (*Hansford 14, R 233*).

The organism was not isolated by Reinking, but was obtained through the courtesy of Mr. C. G. Hansford, of Jamaica.

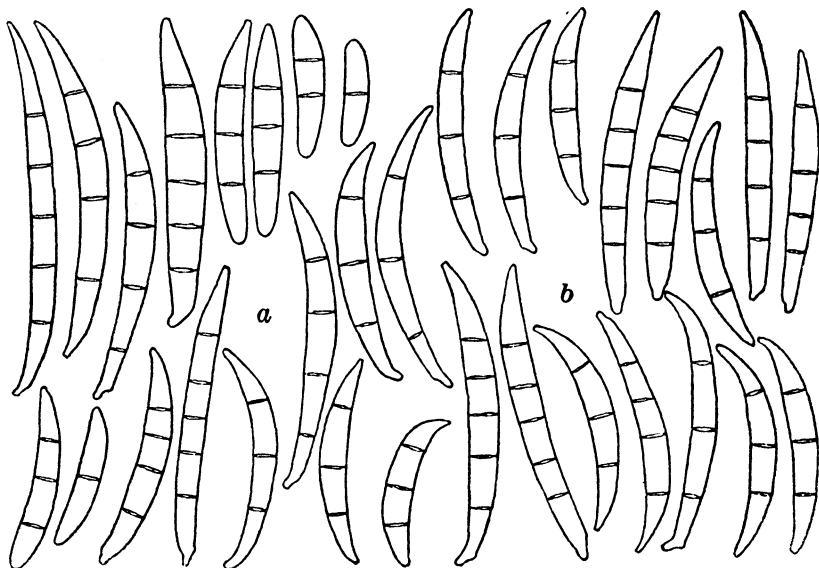


FIG. 8. *Fusarium bullatum* Sherbakoff var. *minus* Wollenweber and Reinking; a, conidia from sporodochia of 14-day-old *Alnus*-stem culture; b, conidia from mycelium and pionnotes of 1-month-old potato-tuber plug culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—In 2-month-old potato-agar tubes a white, medium thin, matted growth is produced over the slant. On potato-agar plates of the same age the aërial growth is scant and pale pinkish buff.

Oat agar.—Cultures 1 month old have a dense, matted, felty growth that is white and cartridge buff above and pale cinnamon pink at the base.

Rice.—On cultures 2 months old a white, medium dense mass of mycelium is produced.

Potato-tuber plug.—Cultures 2 months old have a whitish, matted, felty, and leathery growth over the potato.

Melilotus stem.—On stems 1 month old a medium scant, fine, cottony, white mycelium is produced.

Alnus stem.—One-month-old culture has a white and pale pinkish cinnamon, dense mycelial growth on the top of the stem and a medium scant and fine woolly growth over sides. Pinkish cinnamon tuberculate sporodochia may be produced in abundance over the stem.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Potato-tuber plug; cultures 1 month old; conidia from mycelium:

Conidia—

0-septate.

1-septate, 8 per cent.

2-septate, 7 per cent.

3-septate, 80 per cent, 32 by 3.5 (29 to 35 by 3 to 4) μ .

4-septate, 3 per cent.

5-septate, 2 per cent, 39 by 4 (36 to 42 by 3.5 to 4.5) μ .

Alnus stem; culture 14 days old; conidia from sporodochia:

Conidia—

0-septate, rare.

1-septate, 1 per cent.

2-septate, rare.

3-septate, 97 per cent, 30 by 3.5 (21 to 40 by 3 to 4) μ .

4-septate, 1 per cent, 37 by 3.5 (30 to 45 by 3.5 to 3.75) μ .

5-septate, 1 per cent, 37 by 3.75 (33 to 42 by 3.5 to 4.25) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 90 per cent, 31 by 3.5 (21 to 40 by 3 to 4) μ .

4-septate, 2 per cent, 37 by 3.5 (30 to 45 by 3.5 to 3.75) μ .

5-septate, 2 per cent, 38 by 3.75 (33 to 42 by 3.5 to 4.5) μ .

FUSARIUM BULLATUM Sherbakoff var. **BREVIUS** Wollenweber and Reinking. Text fig. 9.

Fusarium bullatum brevius WOLLENWEBER and REINKING, Phytopath. 15 (1925) 160.

Differs from the type species by shorter conidia, 5- (3- to 5-) septate; 5-septate, 31 to 44 by 3 to 4 μ ; 3-septate, 21 to 36 by 2.5 to 3.5 μ ; chlamydospores intercalary in mycelium and conidia, 1-celled, 2-celled, in clusters.⁵

Habitat.—On dead hibiscus stems (*Hibiscus rosa-sinensis* Linnæus) and decaying banana leaves and plant parts (*Musa sapientium* Linnæus (R 47)). Tela, Honduras, Central America (Reinking R 47).

⁵ From *F. bullatum* var. *minus* it differs by higher-separated and a little broader conidia.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—On 12-day-old agar slants pale pinkish buff, dense mycelium is produced in places. At the base it may be buckthorn brown. Salmon and salmon buff patches of pionnotes may be produced here and there. Older cultures, up to 3 months of age, have a scant white to cartridge buff and light pinkish cinnamon and cinnamon mycelium. Pinkish cinnamon and cinnamon pionnotes masses may be present. On 2-month-old agar plates a white, thin, zonate, matted mycelium is present.

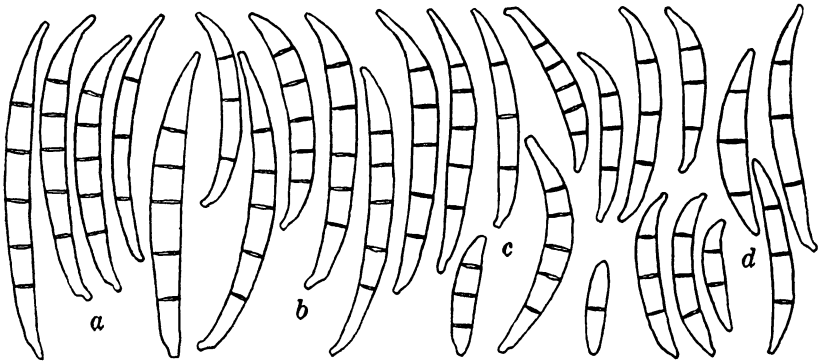


FIG. 9. *Fusarium bullatum* Sherbakoff var. *brevius* Wollenweber and Reinking; a, conidia from pionnotes of 8-day-old hard potato-agar culture; b, conidia from pionnotes of 7-day-old oatmeal-agar culture; c, conidia from pionnotes of 5-day-old hard potato-agar culture; d, conidia from pionnotes of 8-day-old *Melilotus*-stem culture.

Oat agar.—In tubes 1 month old a pale pinkish buff, dense, matted mycelium is produced on the slant. Tawny olive and Saccardo's umber may be present in spots, especially at the base. A light vinaceous cinnamon pionnotes may be produced.

Potato-agar plate, 5 per cent dextrose.—A pinkish cinnamon, medium dense, matted mycelium is produced after one month's growth. The substratum is clay color and tawny olive.

Rice.—Cultures 19 days old have a pale ochraceous buff, cinnamon buff and clay color, dense, matted mycelium above. At the base and sides the mycelium may be chestnut brown and pale salmon color when conidia are produced. Cultures 2 months old are snuff brown and hister on top with a leathery mycelium. On the sides the growth may be pale pinkish buff and cinnamon buff and at the base pale cinnamon pink. Flesh ocher spots may also be present. A pinkish buff pionnotes may be found in places.

Potato-tuber plug.—Cultures 3 months old are light buff on top with cinnamon buff and clay color. An ochraceous salmon

or pale pinkish buff pionnotes may be present. Cultures between 2 and 3 months old have a pinkish buff, cinamon buff, felty mycelium in places. At the base the mycelium is leathery and tawny olive with Saccardo's umber. Blackish brown⁽³⁾ plectenchymic bodies may be present in places.

Melilotus stem.—Two-month-old growth is characterized by a pale pinkish buff, dense, matted mycelium over the stem.

Alnus stem.—One-month-old growth is characterized by a pale pinkish buff, scant mycelium that is powdery in places. A pinkish buff pionnotes may be produced.

Green bean pod.—Green bean-pod cultures 1 to 2 months old have a cartridge buff, cream buff, pinkish buff, and cinnamon buff, dense, matted, mycelial growth.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; cultures 12 days old; conidia from pionnotes:

Conidia—

0-septate.

1-septate, 5 per cent, 16 by 2.5 (14 to 18 by 2.25 to 2.75) μ .

2-septate, 3 per cent, 19 by 2.75 (19 by 2.5 to 3.5) μ .

3-septate, 50 per cent, 29 by 3 (22 to 34 by 2.5 to 3.5) μ .

4-septate, 18 per cent, 30 by 3.5 (25 to 40 by 3 to 4) μ .

5-septate, 24 per cent, 35 by 3.5 (28 to 45 by 3 to 4) μ .

Oat agar; culture 2 weeks old; conidia from pionnotes:

Conidia—

3-septate, 7 per cent, 28 by 3 (21 to 36 by 2.5 to 3.75) μ .

4-septate, 5 per cent.

5-septate, 88 per cent, 38 by 3.5 (31 to 45 by 3 to 4) μ .

Rice; culture 50 days old; conidia from pionnotes:

Conidia—

3-septate, 30 by 2.6 (25 to 36 by 2.5 to 2.75) μ .

4-septate.

5-septate, 38 by 3.5 (33 to 44 by 3 to 4) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

3-septate, 28 per cent, 29 by 3 (21 to 36 by 2.5 to 3.75) μ

4-septate, 12 per cent, 30 by 3.5 (25 to 40 by 3 to 4) μ .

5-septate, 56 per cent, 37 by 3.5 (28 to 45 by 3 to 4) μ .

FUSARIUM BULLATUM Sherbakoff. Text fig. 10.

Fusarium bullatum SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 198; WOLLENWEBER and REINKING, Phytopath. 15 (1925) 159.

Sherbakoff has described this fungus under his section *Ferruginosum* with sickle-shaped, pedicellate, mostly 5-septate, 42

by 4.3 (31 to 47 by 4.1 to 4.9) μ , cream or salmon color conidia; chlamydospores intercalary, in chains or in clusters; stroma from hyaline to pale golden.

Habitat.—On dead floral parts at the tip of banana fruit (*Musa sapientium* Linnæus) (R 54), in the air and soil. Tela, Honduras, Central America (Reinking R 54).

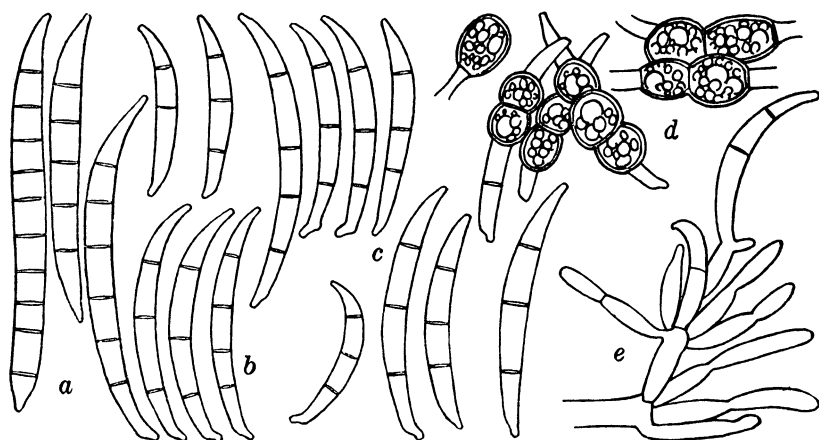


FIG. 10. *Fusarium bullatum* Sherbakoff; a, conidia, large, straight, nonpedicellate, from pionnotes in mycelium of 6-day-old hard potato-agar culture; b, conidia, smaller, pedicellate, from pionnotes and mycelium of 5-day-old hard potato-agar culture; c, conidia from pionnotes in mycelium of 6-day-old hard potato-agar culture; d, chlamydospores from 8-month-old hard potato-agar culture; e, conidiophore from 5-day-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

The growth on various media is similar to that discussed under *F. bullatum* var. *brevius* Wollenweber and Reinking.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 6 days old; conidia from pionnotes:

Conidia—

3-septate, 23 per cent, 35 by 3 (32 to 40 by 3 to 3.25) μ .

4-septate, 16 per cent, 33 by 3.75 (29 to 44 by 2.75 to 5) μ .

5-septate, 61 per cent, 37 by 4 (29 to 47 by 3 to 4.5) μ .

Oat agar; culture 14 days old; conidia from pionnotes:

Conidia—

3-septate, 20 per cent.

4-septate, 27 per cent.

5-septate, 53 per cent.

Melilotus stem; culture 14 days old; conidia from pionnotes:

Conidia—

5-septate, 44 by 3.5 (40 to 48 by 3.5 to 3.75) μ .

Green bean pod; culture 12 days old; conidia from mycelium and pionnotes:

Conidia—

1-septate, 2 per cent, 17 by 3.5 (16 to 18 by 3 to 4) μ .

2-septate, 1 per cent, 21 by 3.5 μ .

3-septate, 62 per cent, 27 by 4 (18 to 36 by 3.25 to 4.5) μ .

4-septate, 29 per cent, 38 by 4 (32 to 45 by 3.5 to 4.5) μ .

5-septate, 6 per cent, 35 by 4.5 (33 to 43 by 4 to 5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

3-septate, 35 per cent, 33 by 3.75 (18 to 40 by 2.5 to 4.5) μ .

4-septate, 21 per cent, 36 by 3.75 (29 to 45 by 2.75 to 5) μ .

5-septate, 40 per cent, 39 by 4 (29 to 48 by 3 to 5) μ .

FUSARIUM OSSICOLUM (Berkeley and Curtis) Saccardo. Plate 1, fig. 6; text fig. 11.

Fusarium ossicolum SACCARDO, Syll. Fung. 4 (1886) 714; WOLLENWEBER, Ann. Myc. 15 (1917) 15.

Light orange mycelium and conidial mass; conidia in sporodochia and pionnotes, curved spindle-shaped, sickle-shaped, middle cells broad in comparison with the longer end cells, end cell often slender, pointed and often curved; 5- (3- to 5-) septate, 27 to 48 by 3.75 to 4.5 μ ; 0-septate, 9 to 11 by 3 to 4.5 μ ; 3-septate, 23 to 26 by 3.75 μ ; 4-septate, 23 to 26 by 4.5 to 6.25 μ ; chlamydospores, intercalary or sometimes terminal.

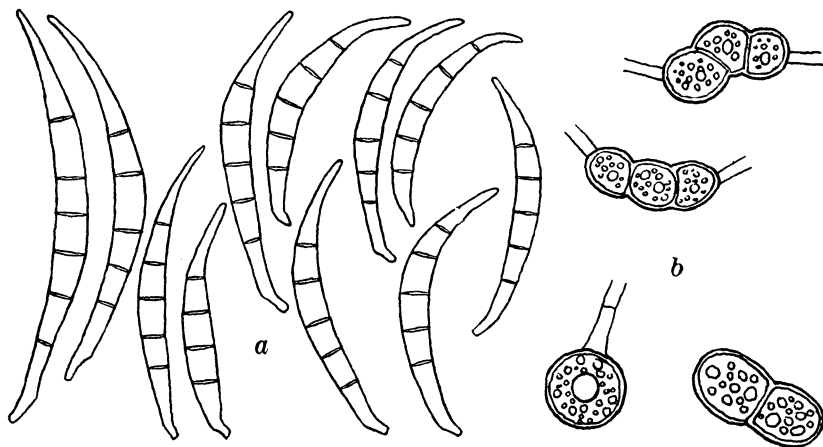


FIG. 11. *Fusarium ossicolum* (Berkeley and Curtis) Saccardo; a, conidia from pionnotes of 1-month-old oatmeal-agar culture; b, chlamydospores, terminal and intercalary, from 1-month-old hard potato-agar culture.

Habitat.—On decaying banana leaves (*Musa sapientium* Linnaeus). Jamaica (Hansford 18, R 237).

The fungus was not isolated by Reinking, but was obtained through the courtesy of Mr. C. G. Hansford, of Jamaica.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 3 months old on agar have a white, medium dense, thin cottony mycelium. Pinkish buff pionnotes masses are present in places. Growth on 2-month-old potato-agar plates is pale cinnamon pink and medium thin. Light vinaceous cinnamon and pinkish cinnamon mycelium may be produced.

Potato-agar plate, 5 per cent dextrose.—The aërial mycelium is thick, matted, felty, and pale pinkish buff, cinnamon buff, and tawny olive. The mycelium in the substratum is russet.

Oat agar.—Cultures 1 month old have a white and pale cinnamon pink, dense, felty, mycelial growth with sayal brown and snuff brown in spots at the base of the slant where it touches the glass. A vinaceous cinnamon pionnotes may be produced.

Rice.—Cultures 2 months old have a dense, matted mycelium that is snuff brown on top, bone brown at the base, and chocolate in places.

Potato-tuber plug.—Cultures 2 months old have a growth similar to that on rice.

Melilotus stem.—Cultures 1 month old have a dense, thick, fine, cottony, pinkish buff mycelium over the stem.

Alnus stem.—Cultures 1 month old have a dense, thick, pinkish buff, pale pinkish cinnamon, and cinnamon buff mycelium in places over the twigs. A light pinkish cinnamon pionnotes may be produced in spots.

MEASUREMENTS OF CONIDIA

Oat agar; culture 1 month old; conidia from pionnotes:

Conidia—

0-septate, 6 per cent, 10 by 3.75 (9 to 11 by 3 to 4.5) μ .

1-septate.

2-septate.

3-septate, 9 per cent, 24 by 3.75 (23 to 26 by 3.75) μ .

4-septate, 6 per cent, 24 by 4.75 (23 to 26 by 4.5 to 5.25) μ .

5-septate, 79 per cent, 36 by 4.25 (27 to 48 by 3.75 to 4.5) μ .

FUSARIUM FALCATUM Appel and Wollenweber. Text fig. 12.

Fusarium falcatum APPEL and WOLLENWEBER, Arb. Kais. Biol. Anst. Land- u. Forstw. 8 (1910) 175–185; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 135; WOLLENWEBER, Ann. Myc. 15 (1917) 15.

Mycelium white to ocher. Conidial masses ocher, yellowish brown, or reddish ocher. Conidia, sporodochia, and pionnotes present; curved spindle-shaped, sickle-shaped, middle cells very broad in comparison with the much longer end cells, with long

and narrow apex, prominently pedicellate, parabolic to hyperbolic curved, typically 5- (3- to 5-) septate, 46 by 4.75 (36 to 65 by 3.5 to 6) μ ; 3-septate, 27 by 4 (23 to 32 by 3.5 to 4.5) μ ; 4-septate, 37 by 4 (29 to 42 by 3.5 to 4.5) μ ; rarer 6- to 12-septate; 10-septate, 83 by 5.5 μ ; chlamydospores 6 to 14 μ in diameter, intercalary or sometimes terminal in mycelium and conidia; 1-celled, 2-celled, in chains or in masses.

Habitat.—In soil, Trujillo, Honduras, Central America (*Reinking R 208*). In plant débris, Jamaica (*Hansford 15, R 234*).

Fusarium falcatum has been determined to be a wound parasite causing tomato fruit rot in Germany and the United States.

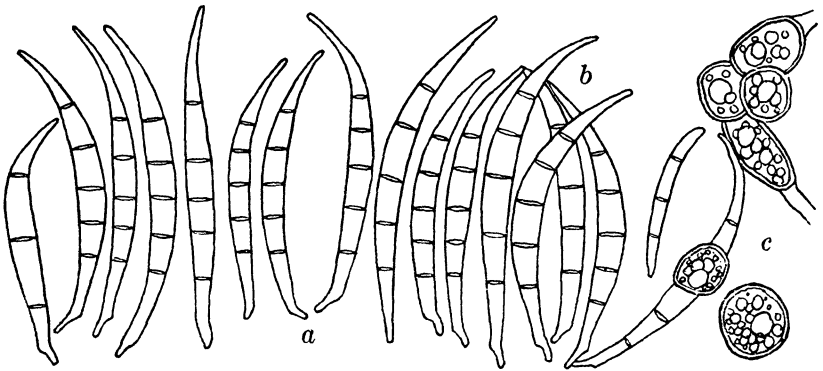


FIG. 12. *Fusarium falcatum* Appel and Wollenweber; a, conidia from sporodochia of 1-month-old *Alnus*-stem culture; b, conidia from pionnotes of 5-day-old hard potato-agar culture; c, chlamydospores from 15-day-old water culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 2 months old have a scant white mycelium with pale pinkish buff pionnotes over slant. The same type of growth is produced on plates of potato agar 2 months old.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a scant sayal brown aërial mycelium and snuff brown pionnotes. The substratum is snuff brown.

Oat agar.—Cultures 1 month old have a white and pale pinkish buff, medium dense, and matted mycelium over the slant. It may be flattened and cream buff in places.

Rice.—Cultures 2 months old have a snuff brown or bone brown mycelium on top and light vinaceous cinnamon on sides. A light vinaceous cinnamon pionnotes is produced.

Potato-tuber plug.—Cultures 2 months old have a white, medium thin, matted mycelium over the plug. The mycelium may be cartridge buff and cream buff in places.

Melilotus stem.—Cultures 2 months old have a scant, cream buff mycelium on the top of the stem and a pionnotes over the sides of the stem.

Alnus stem.—Cultures 1 month old have a medium dense, fine cottony, pale pinkish cinnamon, and cinnamon buff mycelium in places over the stem.

Green bean pod.—Cultures 2 months old have a scant, pale pinkish buff and pinkish buff mycelium over the bean. A cinnamon pionnotes may be present in places.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 1 month old; conidia from pionnotes:

Conidia—

3-septate, 5 per cent, 26 by 3.75 (25 to 27 by 3.5 to 4) μ .

4-septate, 11 per cent, 33 by 4 (29 to 39 by 3.5 to 4.5) μ .

5-septate, 84 per cent, 40 by 4 (31 to 45 by 3.5 to 4.5) μ .

Hard potato agar; culture 5 days old; conidia from pionnotes:

Conidia—

3-septate, 12 per cent.

4-septate, 33 per cent, 38 by 4 (35 to 42 by 3.75 to 4) μ .

5-septate, 55 per cent, 43 by 4 (39 to 50 by 3.75 to 4.5) μ .

Alnus stem; culture 21 days old; conidia from pionnotes:

Conidia—

5-septate, 42 by 4 (35 to 48 by 3.5 to 4.5) μ .

Green bean pod; cultures 1 month old; conidia from pionnotes:

Conidia—

3-septate, 6 per cent, 28 by 4.25 (23 to 32 by 4 to 4.5) μ .

4-septate, 6 per cent, 39 by 4.25 (36 to 42 by 4 to 4.5) μ .

5-septate, 88 per cent, 41 by 4.25 (33 to 50 by 4 to 4.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

3-septate, 8 per cent, 27 by 4 (23 to 32 by 3.5 to 4.5) μ .

4-septate, 17 per cent, 37 by 4 (29 to 42 by 3.5 to 4.5) μ .

5-septate, 75 per cent, 42 by 4 (31 to 50 by 3.5 to 4.5) μ .

FUSARIUM ACUMINATUM Ellis and Everhart emend. Wollenweber. Text fig. 13.

Fusarium acuminatum ELLIS and EVERHART, Proc. Acad. Sci. Phila. (1895) 441; SACCARDO, Syll. Fung. 14 (1899) 1125-1126; WOLLENWEBER, Journ. Agr. Research 2 (1914) 269-270.

Conidia scattered, in sporodochia or in pionnotes, orange in mass; conidia average as follows: 5-septate, 40 to 70 by 3 to 4 μ ; 4-septate (less common), 30 to 60 by 3 to 4.5 μ ; 3-septate, 20 to 45 by 2.75 to 4.25 μ ; 0, 1, 2, 6, and 7 septations occasionally found; subnormal small conidia may be mistaken for conidia of the section *Discolor*, but normal sporodochia develop on repeatedly whorl-like branched conidiophores, giving the character-

istic conidia of the section *Roseum*; conidia in side view, with hyperbolic or parabolic curves, in contrast to *Fusarium herbarum* (Corda) Fries, the conidia of which are less curved; chlamydospores present, intercalary in mycelium and conidia, sometimes single, but mostly in chains and clusters; blue, globose sclerotia, 50 to 70 μ thick, form a striking contrast to the carmine plectenchymatic thallus on starchy media, such as steamed potato tubers. Both blue and carmine are basic modifications of the fungus, while yellow (on rice) is the acid one, turning blue to purple-violet with the addition of an alkali.

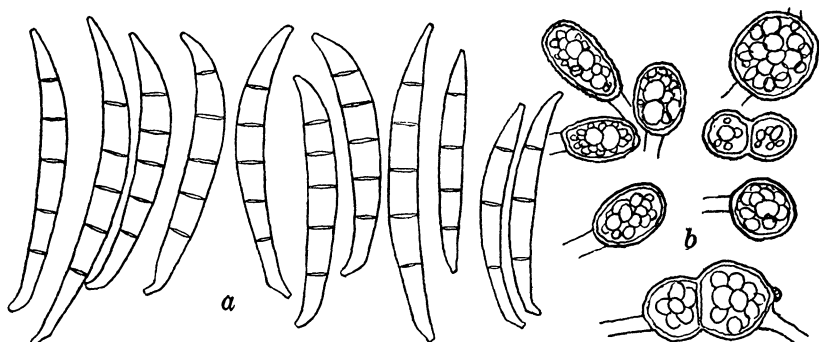


FIG. 18. *Fusarium acuminatum* Ellis and Everhart emend. Wollenweber; a, conidia from mycelium of 16-day-old oatmeal-agar culture; b, chlamydospores from mycelium of 2-month-old hard potato-agar culture.

Habitat.—Spores of the fungus were isolated from the air. Tela, Honduras, Central America (*Reinking R 105*).⁶

Fusarium acuminatum, formerly placed in section *Roseum*, has been placed under the section *Gibbosum* because the conidia have the parabolic dorsal and ventral curvature which is characteristic of this section. Further studies of various strains have led to the observation of intercalary chlamydospores in the mycelium and conidia of this fungus, a character that is also required for the section *Gibbosum*. The presence of carmine mycelium, however, is not a definite character for the section *Roseum* alone as it has been found present in *F. acuminatum* and *F. longipes*, both of which can only be placed in the section *Gibbosum*. These species may be regarded as border-line forms

⁶ *R 105* produced conidia of an average length slightly less than that of the type strain, but the differences in important characters do not warrant separating it as a variety.

with carmine mycelium, otherwise with characters of the section *Gibbosum*, but closely related to those in the section *Roseum*.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old have a white and ivory yellow, thick, dense, matted mycelium over agar with cream buff and buckthorn brown in a few places where it touches the glass. The agar is usually turned spinel red in some places. On potato-agar plates a medium scant, pinkish buff, woolly mycelium is produced.

Potato-agar plate, 5 per cent dextrose.—Cultures 17 days old have a medium dense, matted, pale cinnamon pink aërial mycelium. The mycelium in the substratum is a light vinaceous cinnamon.

Oat agar.—Cultures 17 days old are characterized by an aërial mycelium that is medium dense, matted, and white to pale pinkish cinnamon. On the edges of the slant a rose color and pomegranate purple plectenchymic stroma is usually produced. The agar may be turned coral red in places.

Rice.—Cultures 19 days old have a dense matted mycelium that is white above and mustard yellow and primuline yellow in places. Spots of vinaceous rufous may be present where the mycelium touches the glass. Two-month-old cultures are pinkish buff, cinnamon buff with Indian lake, tawny olive, or Verona brown in places. The mycelium is usually leathery at the base.

Potato-tuber plug.—Cultures 1 to 2 months old have a dense, matted, white mycelium on top with spots of pomegranate purple and Bordeaux red in places below. The oldest cultures may also have Dresden brown and mummy brown in spots.

Green bean pods.—Cultures 1 to 2 months old have a medium scant, matted, white, and cartridge buff mycelium.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 2 months old; conidia from mycelium and pionnotes:

Conidia—

1-septate, 4 per cent, 17 by 3.5 (16 to 18 by 3 to 4) μ .

2-septate, 1 per cent, 26 by 4 μ .

3-septate, 30 per cent, 38 by 4 (31 to 45 by 3.25 to 4.5) μ .

4-septate, 25 per cent, 35 by 3.5 (31 to 46 by 3.25 to 3.75) μ .

5-septate, 40 per cent, 39 by 4 (31 to 45 by 3.25 to 4.5) μ .

Oat agar; culture 16 days old; mycelium and pionnotes:

Conidia—

5-septate, 38 by 4 (33 to 45 by 3.75 to 4.5) μ .

Rice; culture 1 month old; conidia from plectenchymic stroma:

Conidia—

3-septate, 29 per cent, 31 by 3.25 (30 to 32 by 3.25) μ .

4-septate, 28 per cent, 31 by 3.25 (30 to 32 by 3.25) μ .

5-septate, 43 per cent, 35 by 4 (31 to 40 by 3.25 to 4.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 30 per cent, 35 by 3.75 (30 to 45 by 3.25 to 4.5) μ .

4-septate, 26 per cent, 33 by 3.5 (30 to 46 by 3.25 to 3.75) μ .

5-septate, 42 per cent, 37 by 4 (31 to 45 by 3.25 to 4.5) μ .

FUSARIUM CAUDATUM Wollenweber. Text fig. 14.

Fusarium caudatum WOLLENWEBER, Journ. Agr. Research 2 (1914) 262-263.

Conidia with a tail or whiplike prolonged apical cell and a pedicellate base with well-marked heel, ocherous to salmon color

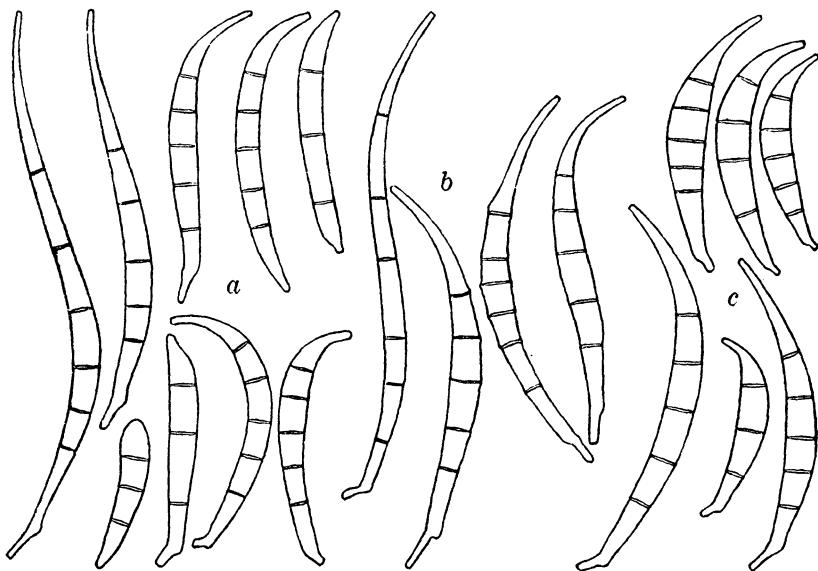


FIG. 14. *Fusarium caudatum* Wollenweber; a, conidia, long type, from sporodochia of 56-day-old rice culture; b, conidia from pionnotes of 15-day-old hard potato-agar culture; c, conidia, short type, from pionnotes of 17-day-old *Melilotus*-stem culture.

in mass, formed in sporodochia and in pionnotes; 5-septate conidia averaging 40 to 80 by 3 to 4.5 μ , lower and higher septations more rarely occur; chlamydospores brown, 7 to 14 μ in diameter, as a rule intercalated in chains or clusters, but frequently single if formed from the content of the cells of conidia under poor conditions, such as in water.

Habitat.—Soil. Jamaica (*Hansford 19a, R 238*). The culture was not isolated by Reinking, but was obtained through the courtesy of Mr. C. G. Hansford, of Jamaica.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—In tubes of hard potato agar 2 months old a medium thin, cottony white mycelium, matted in places, is produced. Light pinkish cinnamon sporodochia and pionnotes masses may be produced in abundance.

Oat agar.—Cultures 1 month old have a scant, fine, cottony, white mycelium. The main part of the slant is covered with a flesh ocher and rufous pionnotes composed of small sporodochia.

Rice.—Cultures 2 months old have a scant, aërial, white and salmon color mycelium on rice. The rice is covered with a flesh ocher and rufous pionnotes.

Potato-tuber plug.—Cultures 2 months old have a matted, white and cinnamon buff mycelium over the potato.

Melilotus stem.—Cultures 1 month old have a scant pinkish buff aërial mycelium on the top of the stem. The sides of the stem are covered with a vinaceous cinnamon pionnotes.

Alnus stem.—Cultures 1 month old are characterized by having a scant pinkish cinnamon mycelium on the top of the twig and a light pinkish cinnamon pionnotes in places over the sides.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Rice; culture 56 days old; conidia from sporodochia.

Conidia—

3-septate, 6 per cent, 27 by 3.75 (21 to 33 by 3.5 to 4) μ .

4-septate, 22 per cent, 32 by 4 μ .

5-septate, 69 per cent, 52 by 3.75 (32 to 74 by 3.5 to 4) μ .

6-septate, 3 per cent, 74 by 3.75 μ .

Melilotus stem; culture 17 days old; conidia from pionnotes:

Conidia—

3-septate, 2 per cent, 25 by 4.5 (24 to 25 by 4.5) μ .

4-septate, 29 per cent, 32 by 4.5 μ .

5-septate, 69 per cent, 36 by 4.5 (27 to 44 by 4 to 5) μ .

Potato agar; culture 15 days old; conidia from pionnotes:

Conidia—

5-septate, 47 by 4 (41 to 52 by 3.5 to 4.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 4 per cent, 26 by 4 (21 to 33 by 3.5 to 4.5) μ .

4-septate, 26 per cent, 32 by 4.25 (32 by 4 to 4.5) μ .

5-septate, 69 per cent, 45 by 4 (27 to 74 by 3.5 to 5) μ .

6-septate, 1 per cent, 74 by 3.75 μ .

FUSARIUM LONGIPES Wollenweber and Reinking. Plate 1, fig. 7; text fig. 15.

Fusarium longipes WOLLENWEBER and REINKING, Phytopath. 15 (1925) 160.

Stroma spread out or verrucose erumpent, aërial mycelium from white to carmine and ochraceous; conidia in sporodochia and in pionnotes, sometimes in columns, ochraceous to orange, elongate sickle-shaped, parabolically or hyperbolically curved, attenuate with whiplike top end sometimes very much curved, footed basal cell long, 5- (4- to 6-) septate, 63 to 104 by 2.75 to 4 μ ; smaller conidia in aërial mycelium with a short-footed base; 5-septate, 36 to 53 by 3 to 4 μ ; chlamydospores sometimes spined, subverrucose, intercalary, mostly singular, 6 to 9 μ in diameter.

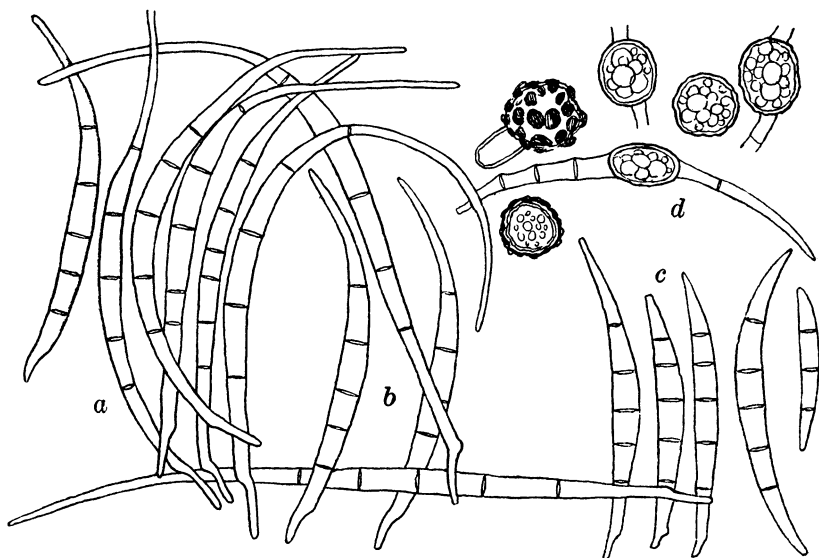


FIG. 15. *Fusarium longipes* Wollenweber and Reinking; a, conidia, typical type, from pionnotes of 3-month-old hard potato-agar culture; b, conidia, short type, from pionnotes of 6-day-old hard potato-agar culture; c, conidia, short type, from sporodochia of 1-month-old *Alnus*-stem culture; d, chlamydospores from 3-month-old hard potato-agar culture and 15-day-old water culture.

Differs from *F. filiferum* (Preuss) Wollenweber in having conidia that are not so broad and in the production of a carmine mycelium.

Habitat.—On mature and living leaves of banana (*Musa sapientium* Linnæus). Tela, Honduras, Central America (Reinking R 34).

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a white, rose color, and pomegranate purple with a Bordeaux ring at the base, thick, dense, and matted mycelium. Older cultures, up to 3 months of age, have a similar mycelial formation, but with the addition of light ochraceous buff sporodochial masses in the center of the growth. The sporodochia may be in columns up to 6 mm long. On potato-agar plates 2 months old a medium thin, white mycelium is present over the top of the plate. Light ochraceous salmon sporodochia are also produced. The mycelium in the substratum is zonate with concentric rings of pale pinkish buff and spinel red mycelium.

Potato-agar plate, 5 per cent dextrose.—One-month-old plates have a medium dense, thick, matted, cameo pink, and spinel red mycelium over the surface. The mycelium in the substratum is spinel pink and spinel red.

Oat agar.—Cultures 1 month old have a thick, dense, matted, white, pale cinnamon pink, seashell pink, pomegranate purple, and Bordeaux mycelium. Apricot buff pionnotes masses are produced over the mycelium in places.

Rice.—Nineteen-day-old cultures have a medium dense, matted mycelium, white above, and lower a pomegranate purple. The mycelium may be also in places pale flesh color, cadmium yellow, and raw sienna. Two-month-old cultures are the same, with the addition of yellow ocher, buckthorn brown, cinnamon brown, and mummy brown in places. Vinaceous cinnamon sporodochia, sometimes in columns, are usually produced.

Potato-tuber plug.—Cultures 1 month old have an aërial, cottony, or dense, matted, white mycelium with pomegranate purple coloration at the base. Older cultures, up to 80 days old, are in the main the same, however, with a leathery mycelium that is cartridge buff, dark olive gray, and pomegranate purple in places.

Melilotus stem.—Cultures 1 month old have a medium dense, pale ochraceous buff mycelium over the stems. Few ochraceous salmon sporodochia are produced.

Alnus stem.—Cultures 1 month old have a scant pale ochraceous buff mycelium in places over the stem. Light ochraceous salmon sporodochia develop from the lenticels of the twig.

Green bean pod.—Cultures between 2 and 3 months old have a dense, matted and leathery, white, cartridge buff, pinkish buff, with spots of pomegranate purple mycelium over the pod.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 12 days old; conidia from sporodochia:

Conidia—

4-septate, 3 per cent, 63 by 3.5 μ .

5-septate, 94 per cent, 72 by 4 (63 to 79 by 3.75 to 4) μ .

6-septate, 3 per cent, 94 by 4 μ .

Hard potato agar; culture 9 days old; conidia from sporodochia:

Conidia—

5-septate, 100 per cent, 86 by 3.75 (73 to 104 by 3.5 to 4) μ .

Alnus stem; culture 1 month old; conidia from sporodochia:

Conidia—

4-septate, 12 per cent.

5-septate, 88 per cent, 45 by 3.5 (36 to 53 by 2.75 to 4) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

4-septate, 5 per cent, 63 by 3.5 μ .

5-septate, 94 per cent, 79 by 3.75 (63 to 104 by 2.75 to 4) μ .

6-septate, 1 per cent, 94 by 4 μ .

VII. Section ROSEUM Wollenweber

Roseum WOLLENWEBER, Phytopath. 3 (1913) 32; SHERBAKOFF, N. Y.

(Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 142; WOLLENWEBER,

Ber. der Deutsch. Bot. Gesell. 35 (1918) 739.

Conidia broad ellipsoid, typically of an even diameter for a considerable part of their length, comparatively narrow, very gradually attenuate toward both ends, approaching sickle-shape, top cell long, sometimes narrow filiform, base more or less pedicellate; chlamydospores absent; some species have blue sclerotia. Color type, acid color modification of aëral mycelium yellow except in *Fusarium anthophilum* and other related fungi.

FUSARIUM ANTHOPHILUM (A. Braun) Wollenweber. Plate 1, fig. 8; text fig. 16.

Fusarium anthophilum BRAUN, Rabenhorst Fungi Europaei, No. 1964

(1875); WOLLENWEBER, Ann. Myc. 15 (1917) 14; WOLLENWEBER

and REINKING, Phytopath. 15 (1925) 160.

Stroma pale, never carmine, conidia scattered, in pionnotes, seldom in sporodochia, slender, attenuate at both ends, sickle-shaped, similar to *F. herbarum* Corda, pedicellate, 3- to 5-septate, 35 to 70 by 2.5 to 4 μ (30 to 82 by 2.5 to 4.5) μ , rarely 6- to more-septate, scattered conidia lanceolate, slightly curved, attenuate at both ends, apedicellate or appendicular; chlamydospores absent.

Habitat.—On dead inflorescence of Rangpur lime (*Citrus aurantifolia* Swingle), on dead leaves of carrot (*Daucus carota* Linnæus), on decaying peduncle and plant trash of banana (*Musa sapientium* Linnæus), on dried pod of bush bean (*Phaseolus vulgaris* Linnæus), on dead cacao twigs (*Theobroma cacao* Linnæus) (R 97), and in soil and air. Tela, Honduras, Central America (Reinking R 97).

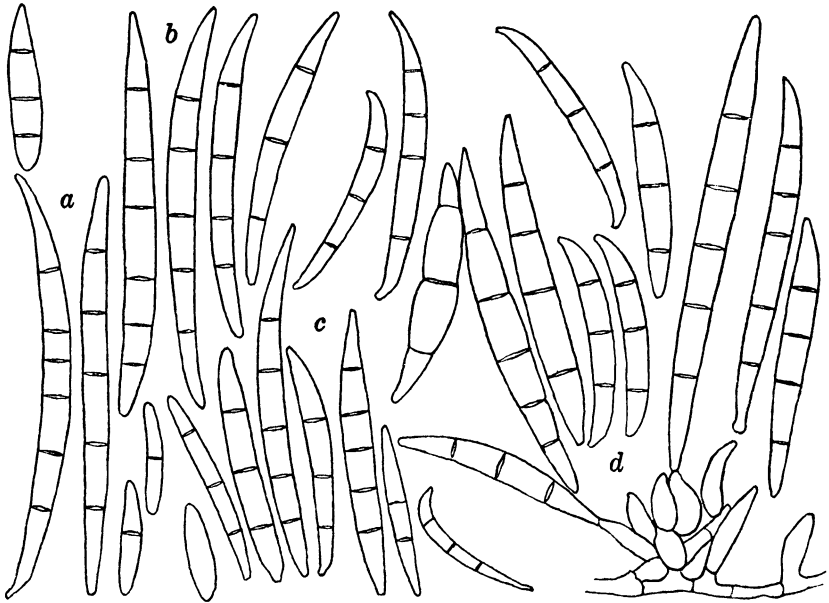


FIG. 16. *Fusarium anthophilum* (A. Braun) Wollenweber; a, conidia, long type, from pionnotes of 14-day-old oatmeal-agar culture; b, conidia from mycelium of 10-day-old hard potato-agar culture; c, conidia, short type, from pionnotes of 34-day-old rice culture; d, conidia and conidiophore from sporodochia of 34-day-old *Melilotus*-stem culture.

Fusarium anthophilum (A. Braun) Wollenweber is common on decaying and dead parts of various hosts. It can also be generally isolated from soil and air. Its pathogenicity has not been fully tested. Soil inoculations about banana plants failed to produce infection.(7)

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 2 to 11 days old have a dense, chiefly pale pinkish buff with tawny olive mycelium. Salmon buff and salmon pionnotes masses may be produced. Older cultures, up to 3 months old, are medium dense to matted and light buff, light pinkish cinnamon with buckthorn brown, cin-

namon brown, and mummy brown in places. The pionnotes in older cultures is light pinkish cinnamon.

Oat agar.—Cultures 1 month old have a dense, matted, pale pinkish buff aërial mycelium with pinkish buff and cinnamon buff on the sides of the slant.

Rice.—Cultures 20 days old are characterized by having a medium dense and matted, pale pinkish buff and pinkish buff mycelium. The mycelium also may be in places buckthorn brown and flesh color around the edge of the rice on the glass. Older cultures, from 1 to 2 months old, are leathery and at first Verona brown, pinkish cinnamon, and vinaceous cinnamon, and later pale pinkish buff or pinkish buff with buckthorn brown at the base, and flesh color around the edge of the rice on the glass. A light buff, salmon buff, or even apricot orange pionnotes may be produced.

Potato-tuber plug.—Cultures 21 days old have a dense matted, felty, white, pale ochraceous salmon mycelium with seashell pink, clay color or sepia where it touches the glass. Older cultures, from 1 to 3 months old, are dense, matted, leathery in places, cartridge buff, warm buff, and chamois at first, later turning to ivory yellow, pinkish buff, cinnamon buff, or wood brown. The growth in the oldest cultures may be leathery and wrinkled. A light ochraceous salmon pionnotes may be present.

Melilotus stem.—Cultures 2 months old have a medium dense, pale pinkish buff mycelium with yellow ocher where it touches the glass.

Alnus stem.—Cultures 1 month old have a medium scant, pale pinkish cinnamon mycelium. A light vinaceous cinnamon pionnotes is usually produced.

Banana peel.—Cultures 26 days old have a scant, cottony, white and pinkish buff mycelium. Older cultures, 3 months old, have no aërial mycelium, but have a cinnamon pionnotes and blackish green-gray sclerotia in wartlike heaps, 0.5 to 4 mm in diameter.

Green bean pod.—Cultures 16 days old have a dense, matted, light buff and buckthorn brown mycelium with a light ochraceous salmon pionnotes. Older cultures, between 1 and 2 months old, are primarily characterized by a medium dense, matted, cartridge buff mycelium with pale pinkish cinnamon, cream buff, and chamois in places.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 18 days old; conidia from pionnotes:

Conidia—

1-septate, 2 per cent, 16 by 2.75 μ .

2-septate.

3-septate, 23 per cent, 26 by 3.5 (18 to 30 by 3 to 4) μ .

4-septate, 19 per cent, 40 by 3.5 (32 to 45 by 3 to 4) μ .

5-septate, 56 per cent, 44 by 3.75 (36 to 50 by 3.5 to 4) μ .

Hard potato agar; culture 30 days old; conidia from mycelium:

Conidia—

0-septate, 2 per cent, 11 by 2.75 (11 to 12 by 2.75) μ .

1-septate, 4 per cent, 18 by 3 (17 to 20 by 2.75 to 3.5) μ .

2-septate, 3 per cent, 21 by 3.5 μ .

3-septate, 41 per cent, 30 by 3.75 (22 to 44 by 3.25 to 4.5) μ .

4-septate, 8 per cent, 38 by 4.5 (34 to 45 by 4.5) μ .

5-septate, 34 per cent, 42 by 4.25 (32 to 50 by 3.5 to 5) μ .

6-septate, 4 per cent, 48 by 4.75 (47 to 49 by 4.5 to 5) μ .

7-septate, 2 per cent.

8-septate, 1 per cent, 50 by 5 (50 to 51 by 5 to 5.5) μ .

9-septate, 1 per cent, 53 by 4.75 (51 to 55 by 4.5 to 5) μ .

Oat agar; culture 16 days old; conidia from pionnotes:

Conidia—

3-septate, 13 per cent.

4-septate, 12 per cent.

5-septate, 74 per cent.

6-septate, 1 per cent.

Rice; culture 2 months old; conidia from pionnotes:

Conidia—

1-septate, 2 per cent.

2-septate, 2 per cent.

3-septate, 50 per cent, 36 by 3 (31 to 40 by 2.5 to 3.5) μ .

4-septate, 11 per cent.

5-septate, 35 per cent, 67 by 3.5 (37 to 82 by 3 to 4.5) μ .

6-septate, 57 by 3.75 μ .

Green bean pod; culture 6 days old; conidia from mycelium:

Conidia—

0-septate, 1 per cent, 11 by 3.5 μ .

1-septate, 4 per cent, 17 by 4.5 (14 to 20 by 3.5 to 6) μ .

2-septate, 2 per cent, 19 by 3.5 (19 to 20 by 3.5) μ .

3-septate, 39 per cent, 31 by 4 (24 to 38 by 3.5 to 5.25) μ .

4-septate, 13 per cent, 39 by 5 (32 to 44 by 4 to 6.25) μ .

5-septate, 41 per cent, 44 by 5 (38 to 52 by 3.5 to 6.00) μ .

Green bean pod; culture 14 days old; conidia from mycelium:

Conidia—

0-septate, 1 per cent, 11 by 4.5 μ .

1-septate, 12 per cent, 15 by 2.75 (14 to 18 by 2.75 to 3) μ .

2-septate, 4 per cent, 20 by 3.5 (19 to 29 by 2.75 to 4.5) μ .

- 3-septate, 43 per cent, 26 by 3.5 (21 to 34 by 2.75 to 4) μ .
 4-septate, 4 per cent, 34 by 4 (32 to 36 by 3.5 to 4.5) μ .
 5-septate, 27 per cent, 43 by 4.25 (37 to 48 by 4 to 5) μ .
 6-septate, 6 per cent, 49 by 4.75 (49 to 50 by 4.5 to 5) μ .
 7-septate, 1 per cent, 48 by 4.75 (46 to 51 by 4.5 to 5) μ .
 8-septate, 1 per cent, 57 by 5 (50 to 60 by 4.5 to 5.25) μ .
 9-septate.
 10-septate, 1 per cent, 59 by 5.25 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 35 per cent, 30 by 3.5 (18 to 44 by 2.5 to 5.25) μ .
 4-septate, 11 per cent, 38 by 4.25 (32 to 45 by 3 to 6.25) μ .
 5-septate, 45 per cent, 48 by 4.25 (32 to 82 by 3 to 5.25) μ .

VIII. Section LISEOLA Wollenweber, Sherbakoff, Reinking, Johann, and Bailey

Section *Moniliforme* Sherbakoff; subsection *Constrictum* Wollenweber;
 section *Liseola* WOLLENWEBER, SHERBAKOFF, REINKING, JOHANN,
 and BAILEY, Journ. Agr. Research 30 (1925) 841.

Microconidia more or less formed in chains, spindle to ovoid in shape; macroconidia slender with a slightly constricted top end, and a pedicellate base, form and color similar to section *Lateritium*, scattered, in sporodochia or in pionnotes, brownish white to orange cinnamon; chlamydospores absent; stroma vinaceous to violet, spread out or erumpent, often with sclerotia. Conidial stage of *Gibberella* section *Lisea* (Saccardo) Wollenweber.

FUSARIUM MONILIFORME Sheldon. Plate 1, fig. 9; text fig. 17.

Fusarium moniliforme SHELDON, 17th Annual Report, Nebraska Agr. Exp. Sta. 1903 (1904) 23-32; SACCARDO, Syll. Fung. 22: 1485; WOLLENWEBER, Ann. Myc. 15 (1917) 23; WOLLENWEBER and REINKING, Phytopath. 15 (1925) 162; WINELAND, GRACE O., Journ. Agr. Research 28 (1924) 909-922 (an ascigerous stage and synonymy for *Fusarium moniliforme*).

Wineland has named this fungus *Gibberella moniliformis* (Sheldon) Wineland and discusses its possible relation to *Gibberella acervalis* (Moug.) Wollenweber.

Microconidia in chains or in false heads formed in white to Isabella color, aërial mycelium, spindle to ovoid in shape, 5 to 12 by 2.25 to 4 μ ; macroconidia delicate and slender, sickle-shaped, attenuate, pedicellate, scattered or in sporodochia or pionnotes, brownish white to orange cinnamon; mostly 3-septate, 30 to 36 by 3 to 3.5 (23 to 48 by 2.25 to 4) μ , fewer 1-, 4-, 5-septate; 1-septate, 12 to 18 by 2.25 to 3.5 μ ; 4-septate, 37 to 53 by 3 to 3.5 μ ; 5-septate, 43 to 66 by 3 to 3.5 μ ; chlamydospores absent; sclerotia blue, stroma violet or ochraceous.

Under certain conditions some cultures produce blue to almost black *Gibberella*-like sclerotia up to 0.5 mm.

Habitat.—On diseased kernels of corn (*R* 73), on cut ends of corn stems and cob (*Zea mays* Linnæus); on leaves, in interior of diseased pseudostems, and on dead floral parts (*R* 53) of banana (*Musa sapientium* Linnæus), on decaying undetermined plant, and in soil and air. Tela and Trujillo, Honduras, Central America (*Reinking R* 53, *R* 73). On rotting bud leaves of pineapple (*Ananas sativus* Schultes). Jamaica (*Hansford* 5, *R* 225).

Fusarium moniliforme is the cause of a corn-mold disease in the United States and Central America.

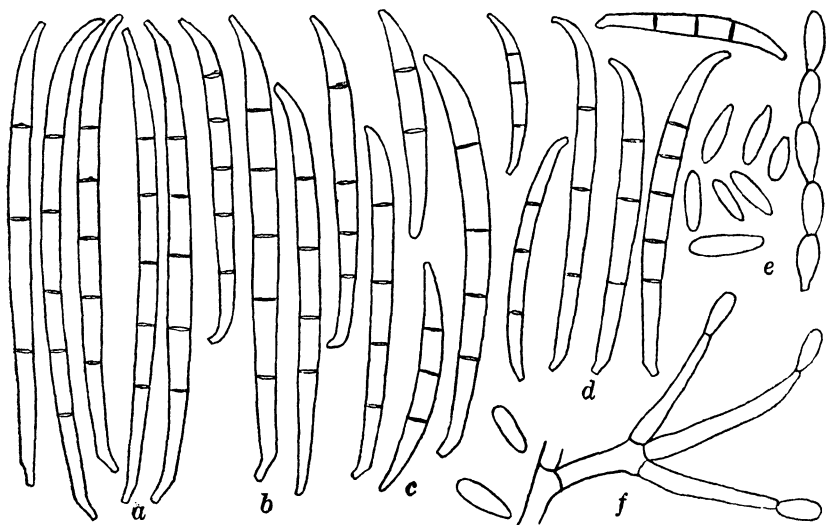


FIG. 17. *Fusarium moniliforme* Sheldon; a, conidia from pionnotes of one-month-old rice culture; b, conidia from pionnotes of 25-day-old potato-tuber plug culture; c, conidia from pionnotes and mycelium of 6-day-old hard potato-agar culture; d, conidia from sporodochia of 1-month-old *Melilotus*-stem culture; e, microconidia, some in chains, from mycelium of 5-day-old hard potato-agar culture; f, conidiophore, portion of, from mycelium of 5-day-old hard potato-agar plate culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a scant, medium coarse, pale pinkish buff and pale pinkish cinnamon mycelium, tufted in places. Dusky bluish green spots are usually present, especially near the base of the slant. Light ochraceous salmon or vinaceous cinnamon pionnotes develop over the slant. Deep slate green *Gibberella*-like sclerotia may develop in certain cultures. Older cultures, up to 3 months of age, have a scant cartridge buff or pale ochraceous buff mycelium

with spots of dusky bluish green here and there. The pionnotal growth over the slant is light buff, pinkish buff, or pinkish cinnamon. Sclerotia if present are black, but blue with transparent light. On potato-agar plates 2 months old a short, twisted, woolly, pale pinkish cinnamon, aërial mycelium is produced. A pale pinkish cinnamon pionnotes usually is present.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have an aërial mycelium that is scant, short, twisted, woolly, and pale grayish vinaceous. The substratum is dark vinaceous brown.

Oat agar.—Cultures 1 month old have a medium dense, thick, matted, white and pinkish cinnamon mycelium. The mycelium may be powdery in places and with spots of nigrosin violet, dark nigrosin violet, and dark bluish gray-green. A pale pinkish cinnamon pionnotes may be present.

Rice.—Cultures 20 days old have a medium dense, thin, matted, thulite pink and spinel red mycelium. At the base it may be leathery and auricula purple and pale salmon color. The rice is turned ochraceous orange, yellow ocher, or mustard yellow. Older cultures, up to 2 months of age, have a medium dense mycelium that is usually pinkish cinnamon, dark maroon-purple, dahlia carmine, and dusky auricula purple. Salmon buff and light ochraceous buff may also occur. The rice is changed to straw yellow or mustard yellow, often with deep slate violet in places. Small, buff pink sclerotia may be present. Spinel red, Indian lake, or cream buff and light pinkish cinnamon pionnotes masses are usually produced.

Potato-tuber plug.—Cultures 21 days old usually have a matted, seashell pink, olive and orange pink with indigo mycelium below. Minute dusky green-blue or deep delft blue sclerotia may be present. Older cultures, from 1 to 2.5 months old, have a rather scant, thin and fluffy, sometimes leathery, aërial mycelium that is seashell pink or light pinkish cinnamon in places, but chiefly dusky slate blue, dusky bluish green, petunia violet, Hortense blue, and deep delft blue. A seashell pink, pinkish buff, vinaceous buff, or light pinkish cinnamon pionnotes is usually present.

Melilotus stem.—Cultures 2 months old are characterized by having a short, scant, woolly and powdery, pale pinkish cinnamon and dusky dull bluish green mycelium over the stem. A light pinkish cinnamon pionnotes is produced.

Mature corn stalk.—Cultures 17 days old have a dense, white mycelium tinged with salmon buff and slight amounts of sea

green. Cultures 1 to 2 months old may have a dense, white and salmon buff mycelial growth.

Banana peel.—Cultures 1 month old have a scant, matted, cartridge buff, cream buff, or pale pinkish buff and cinnamon mycelium. Pale cinnamon pink and light vinaceous cinnamon pionnotes masses or honey yellow, hemispheric sporodochia are usually produced.

Green bean pod.—Cultures 10 days old have a dense, fluffy, white mycelium. Older cultures, up to 3 months of age, are characterized by having a dense, fluffy or thin, matted, pale pinkish cinnamon, light pinkish cinnamon, and pinkish cinnamon mycelium over the bean. Orange cinnamon and Verona brown sporodochia or light pinkish cinnamon pionnotes masses are usually present. Pinkish buff or blackish slate sclerotia may be produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 2 months old; conidia from pionnotes:

Conidia—

- 0-septate, 42 per cent, 9 by 3 (5 to 14 by 1.75 to 3.5) μ .
- 1-septate, 6 per cent, 19 by 3.5 (14 to 23 by 2.75 to 3.5) μ .
- 2-septate, 2 per cent, 22 by 3.25 (21 to 23 by 3 to 3.5) μ .
- 3-septate, 44 per cent, 33 by 3.25 (23 to 45 by 2.75 to 4) μ .
- 4-septate, 4 per cent, 43 by 3.5 (37 to 53 by 3.5) μ .
- 5-septate, 2 per cent, 41 by 4 (41 to 50 by 3 to 3.5) μ .

Rice; culture 21 days old; conidia from pionnotes:

Conidia—

- 3-septate, 33 per cent.
- 4-septate, 27 per cent.
- 5-septate, 40 per cent.

Potato-tuber plug; culture 25 days old; conidia from mycelium and pionnotes:

Conidia—

- 3-septate, 91 per cent.
- 4-septate, 8 per cent.
- 5-septate, 1 per cent.

Melilotus stem; culture 1 month old; conidia from sporodochia:

Conidia—

- 3-septate, 81 per cent, 38 by 2.75 (23 to 46 by 2.25 to 3) μ .
- 4-septate, 14 per cent, 46 by 2.75 (42 to 50 by 2.5 to 3) μ .
- 5-septate, 5 per cent.

Green bean pod; culture 17 days old; conidia from pionnotes:

Conidia—

- 0-septate, 22 per cent, 7 by 2.75 (5 to 10 by 2.25 to 3.5) μ .
- 1-septate, 16 per cent, 12 by 3.5 (11 to 13 by 3.25 to 3.5) μ .
- 2-septate, 4 per cent, 26 by 3.25 (21 to 31 by 3 to 3.5) μ .
- 3-septate, 56 per cent, 34 by 3.25 (27 to 45 by 2.75 to 3.5) μ .
- 4-septate, 1 per cent, 42 by 3.25 (37 to 42 by 3.25) μ .
- 5-septate, 1 per cent, 55 by 3.5 (50 to 63 by 3.5) μ .

Frequently 95 to 100 per cent 0-septate conidia only are produced on the various media.

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

- 0-septate, 15 per cent, 8 by 3 (5 to 14 by 1.75 to 3.5) μ .
- 1-septate, 4 per cent, 15 by 3 (12 to 18 by 2.25 to 3.5) μ .
- 2-septate, 2 per cent, 24 by 3.25 (21 to 31 by 3 to 3.5) μ .
- 3-septate, 61 per cent, 34 by 3 (23 to 48 by 2.25 to 4) μ .
- 4-septate, 9 per cent, 43 by 3.5 (37 to 53 by 3 to 3.5) μ .
- 5-septate, 9 per cent, 47 by 3.5 (43 to 66 by 3 to 3.5) μ .

FUSARIUM MONILIFORME Sheldon var. **ERUMPENS** Wollenweber and Reinking. Plate 1, fig. 10; text fig. 18.

Fusarium moniliforme erumpens WOLLENWEBER and REINKING, Phytopath. 15 (1925) 163.

Differs from the type by having more and larger, rugose, dark blue sclerotia, erumpent and clustered *Gibberella*-like; microconidia in chains; 0-septate, 5 to 14 by 2 to 3 μ ; macroconidia mostly 3- to 5-septate; 3-septate, 22 to 48 by 2.5 to 3.5 μ ; 4-septate, 33 to 47 by 3.25 to 3.5 μ ; 5-septate, 33 to 51 by 3.25 to 3.5 μ ; chlamydospores absent.

Habitat.—In vascular bundles of living, diseased pseudostem of banana (*Musa sapientium* Linnæus). Tela, Honduras, Central America (Reinking R 62).

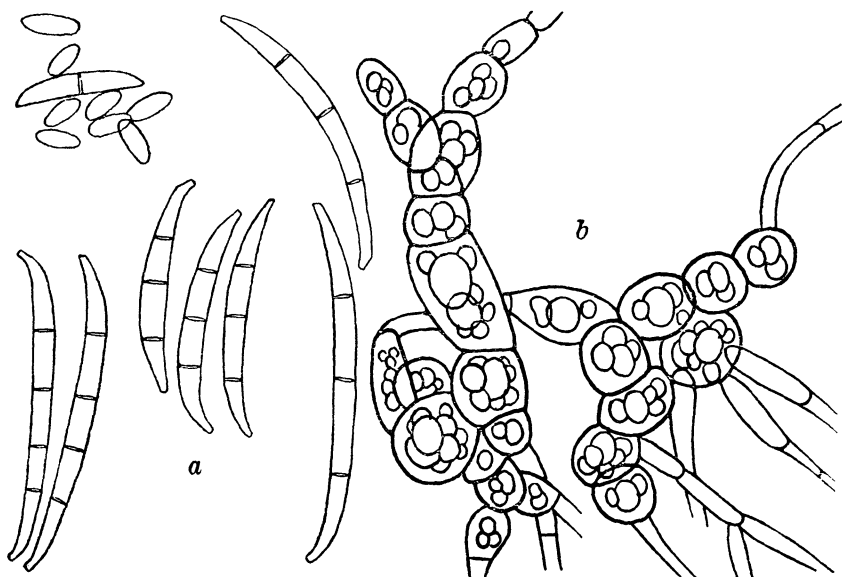


FIG. 18. *Fusarium moniliforme* Sheldon var. *erumpens* Wollenweber and Reinking; a, conidia from mycelium of 22-day-old hard potato-agar culture; b, early formation of sclerotial plectenchyma from mycelium in 14-day-old water culture.

Soil inoculations about banana plants failed to produce infection.(7)

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 5 days old have a medium scant, matted, pale pinkish buff mycelium with a cinnamon buff pionnotes. Older cultures, up to 3 months old, have a cartridge buff and light buff mycelium with spots of bluish slate black. A light buff and light vinaceous cinnamon pionnotes is produced. Potato-agar plates 2 months old have a short, twisted, woolly, aërial mycelium that is pale pinkish buff. A pionnotes of the same color is produced.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a scant tufted aërial mycelium that is pale grayish vinaceous and delft blue, slate violet(1) stromatic bodies are formed. The mycelium in the substratum is burnt lake.

Oat agar.—Cultures 1 month old are characterized by a thick, dense, matted, felty, twisted, white and pale pinkish buff mycelium, woolly in places. Stromatic masses just over agar may be blue-violet-black. An abundance of blue-violet-black sclerotia, 0.5 to 1 mm in diameter, are formed over the base of the slant.

Rice.—Cultures 21 days old have a medium dense, matted, rosolane purple, Schoenfeld's purple, and auricula purple mycelium. It may also be thulite pink in places over the rice. The rice is colored cameo. Older cultures, up to 2 months old, have a matted mycelium above and leathery below that is cameo pink to dark maroon-purple on top with pale cinnamon pink and light vinaceous cinnamon below. The rice is changed to shrimp pink.

Potato-tuber plug.—Cultures 25 days old have a matted, pale pinkish buff and dark delft blue mycelium. Dark bluish gray-green and dusky dull bluish green sclerotia are produced over the potato. Light pinkish cinnamon sporodochia and pionnotes masses are found in places. Older cultures, up to 80 days of age, have a more or less leathery, dusky slate blue mycelium, with dusky slate sclerotia and a tilleul buff pionnotes.

Melilotus stem.—Cultures 2 months old have a medium scant, tufted, and matted mycelium over the stem that is pale pinkish cinnamon with the stromatic masses dusky dull bluish green. Dark delft blue sclerotial masses, 0.5 to 3 mm in diameter, are formed all over the stem. Cinnamon sporodochia may be present.

Alnus stem.—Cultures 1 month old have a scant, aërial, pale vinaceous violet and deep purplish vinaceous mycelium. Sporodochia are produced here and there and are pale pinkish buff.

Banana peel.—Cultures 26 days old have a scant white and pale purplish vinaceous mycelium. Black sclerotia in wart-like heaps are present. Cinnamon and dark grayish olive sporodochia are produced.

Green bean pod.—Cultures 2 to 3 months old have a thin, matted, cartridge buff, cream buff, and cinnamon buff mycelium. A cinnamon buff or tawny olive pionnotes is produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 1 month old; conidia from pionnotes:

Conidia—

- 0-septate, 22 per cent, 9 by 2.5 (5 to 14 by 2 to 2.75) μ .
- 1-septate, 9 per cent, 13 by 2.75 (12 to 15 by 2.75) μ .
- 2-septate, 3 per cent, 19 by 3 (19 to 20 by 2.75 to 3.25) μ .
- 3-septate, 36 per cent, 33 by 3 (22 to 48 by 2.5 to 3.5) μ .
- 4-septate, 12 per cent, 37 by 3.5 (33 to 42 by 3.5) μ .
- 5-septate, 18 per cent, 38 by 3.5 (33 to 43 by 3.5) μ .

Green bean pod; culture 25 days old; conidia from pionnotes:

Conidia—

- 0-septate, 32 per cent, 7 by 2.75 (5 to 10 by 2.25 to 3) μ .
- 1-septate, 9 per cent, 15 by 3 (15 to 16 by 2.75 to 3.5) μ .
- 2-septate, 2 per cent, 18 by 3 (17 to 20 by 2.75 to 3.25) μ .
- 3-septate, 38 per cent, 31 by 3 (22 to 40 by 2.75 to 3.25) μ .
- 4-septate, 9 per cent, 41 by 3.25 (36 to 47 by 3.25 to 3.5) μ .
- 5-septate, 10 per cent, 45 by 3.5 (41 to 51 by 3.25 to 3.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

- 3-septate, 37 per cent, 32 by 3 (22 to 48 by 2.5 to 3.5) μ .
- 4-septate, 10 per cent, 38 by 3.25 (33 to 47 by 3.25 to 3.5) μ .
- 5-septate, 14 per cent, 41 by 3.5 (33 to 51 by 3.25 to 3.5) μ .

FUSARIUM MONILIFORME Sheldon var. **SUBGLUTINANS** Wollenweber and Reinking.

Text fig. 19.

Fusarium moniliforme subglutinans WOLLENWEBER and REINKING,
Phytopath. 15 (1925) 163.

Differs from the type principally in having the microconidia not borne in chains; microconidia unicellular, 6 to 15 by 2 to 3.5 μ ; macroconidia mostly 3-septate, 25 to 38 by 2.75 to 3.5 (18 to 50 by 2.75 to 4) μ ; fewer 1-septate, 10 to 25 by 2.5 to 3.5 μ ; 4-septate, 27 to 50 by 3.25 to 4 μ ; sometimes 5-septate, 43 to 55 by 3.25 to 4 μ ; 6- to 7-septate, 48 to 57 by 3.25 to 4 μ ; chlamydospores absent; sclerotia dark blue.

Habitat.—On decaying leaves and pseudostem, in the vascular bundles and exterior of living pseudostem of banana (*Musa sapientium* Linnæus) and in the air. Tela and Trujillo, Honduras, Central America (*Reinking R 60*).

Soil inoculations about banana plants failed to produce infection.(7)

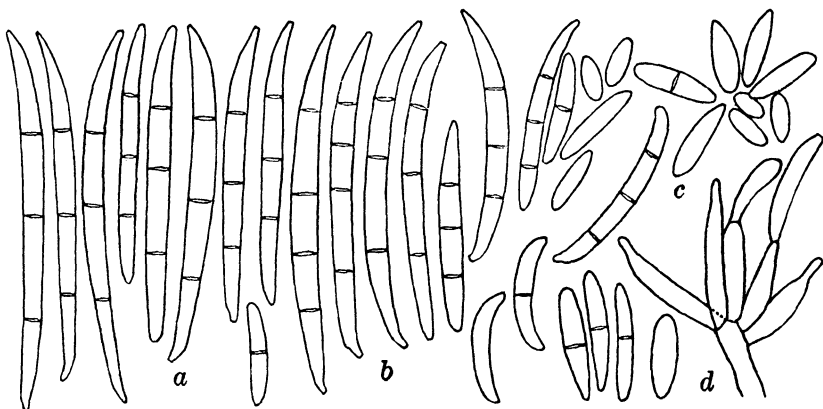


FIG. 19. *Fusarium moniliforme* Sheldon var. *subglutinans* Wollenweber and Reinking; a, conidia from pionnotes of 17-day-old hard potato-agar culture; b, conidia from sporodochia of 1-month-old *Melilotus*-stem culture; c, microconidia from mycelium of 16-day-old hard potato-agar culture; d, conidiophore, portion of, from mycelium of 20-day-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—On 2 to 14-day-old cultures a medium scant, cartridge buff, shell pink, vinaceous pink, and sometimes rosolane purple mycelium is produced. A tawny olive and Saccardo's umber coloration may also be present. A salmon buff pionnotes is formed. Older cultures, up to 3 months old, have a matted, dense, and felty, shell pink, rosolane purple, light pinkish cinnamon growth at the top of the slant, and at the base a growth that is Corinthian red, cinnamon brown, slate purple, and dusky green-blue.(2) The pionnotes is light vinaceous cinnamon or pale ochraceous buff. On potato-agar plates, 2 months old, a short, woolly, and powdery, pale pinkish cinnamon mycelium is produced over the plate.

Potato-agar plate, 5 per cent dextrose.—One-month-old cultures have a scant, pale grayish vinaceous aërial mycelium. The mycelium in the substratum is a burnt lake.

Oat agar.—Cultures 1 month old are characterized by a medium dense, twisted, woolly, pale pinkish cinnamon with deep

slate blue and dusky slate blue mycelium. Spots of dusky slate violet, bluish slate black, deep hyssop violet, and light vinaceous cinnamon may be present in places.

Rice.—Cultures 21 days old have a medium dense and matted, spinel red, rosolane purple, and Schoenfeld's purple mycelium. The rice is turned shrimp pink or neutral red. Older cultures, up to 2 months of age, have a thin, matted, thulite pink, spinel pink, dark maroon-purple, salmon buff, and salmon mycelium over the rice, leathery in places. Spots of yellow ocher may be present. Salmon and light vinaceous cinnamon pionnotes masses are produced. Deep delft blue or blackish brown,⁽¹⁾ small sclerotia may be present. The rice in older cultures is straw yellow and amber yellow. The addition of a 10 per cent solution of potassium hydroxide to a young culture turns the mycelium and substratum dusky auricula purple.

Potato-tuber plug.—Cultures 19 to 30 days old have a scant to dense, matted mycelium that is seashell pink, pale pinkish buff, pale pinkish cinnamon, cameo pink, light mauve, and deep delft blue. Minute deep delft blue sclerotia may be present. Pinkish cinnamon and light vinaceous cinnamon pionnotes masses are formed. Cultures up to 80 days of age have a dense, matted, sometimes leathery, pinkish buff, dusky green-blue,⁽¹⁾ nigrosin violet, dark chessylite blue, and dark bluish gray-green mycelium. Deep delft blue sclerotia may be present. The pionnotes is light ochraceous buff, light pinkish cinnamon, or dark bluish gray-green.

Melilotus stem.—Cultures 2 months old have a thick, dense, matted, aërial mycelium that is pale cinnamon pink. In places the stem is covered with dusky dull bluish green stromatic masses.

Banana peel.—Cultures 26 days old have a medium dense and matted white and pale pinkish buff mycelium. A vinaceous cinnamon pionnotes may be produced. Older cultures have the same appearance.

Banana-fruit flesh.—Cultures 26 days old have a medium dense and matted, deep slate violet and dark livid purple mycelium.

Green bean pod.—Cultures 1 to 2 months old have a thin to dense, matted mycelium that is cartridge buff, pinkish buff, pale pinkish cinnamon, cinnamon buff, and sometimes deep olive buff. A light pinkish cinnamon, light vinaceous cinnamon, or dark olive buff pionnotes is produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 11 days old; conidia from pionnotes:

Conidia—

- 0-septate, 19 per cent, 11 by 2 (9 to 14 by 1.75 to 2.25) μ .
- 1-septate, 65 per cent, 17 by 2.5 (10 to 25 by 2.25 to 3.25) μ .
- 2-septate, 5 per cent, 21 by 2.75 μ .
- 3-septate, 11 per cent, 33 by 3.5 (22 to 32 by 3.75 to 4.5) μ .
- 4-septate, rare.
- 5-septate, rare, 43 by 4.5 μ .
- 6-septate, rare.
- 7-septate, rare, 48 by 4.5 μ .

Hard potato agar; culture 30 days old; conidia from pionnotes:

Conidia—

- 0-septate, 10 per cent, 12 by 3.5 (11 to 15 by 2.75 to 3.5) μ .
- 1-septate, 21 per cent, 18 by 3 (16 to 20 by 2.75 to 3.5) μ .
- 2-septate, 12 per cent, 22 by 3.5 (21 to 23 by 3.5) μ .
- 3-septate, 52 per cent, 33 by 3.5 (24 to 48 by 3.24 to 4) μ .
- 4-septate, 3 per cent, 39 by 3.5 (37 to 41 by 3.5) μ .
- 5-septate, 2 per cent, 47 by 3.25 μ .

Hard potato agar; culture 44 days old; conidia from pionnotes:

Conidia—

- 0-septate, 18 per cent, 10 by 3 (6 to 15 by 2.75 to 3.5) μ .
- 1-septate, 20 per cent, 16 by 3 (10 to 20 by 2.75 to 3.25) μ .
- 2-septate, 3 per cent, 19 by 3 (16 to 22 by 2.75 to 3.25) μ .
- 3-septate, 47 per cent, 38 by 3.5 (23 to 30 by 2.75 to 4) μ .
- 4-septate, 4 per cent, 48 by 3.75 (46 to 50 by 3.25 to 4) μ .
- 5-septate, 7 per cent, 53 by 3.75 (51 to 53 by 3.5 to 4) μ .
- 6-septate, 1 per cent, 51 by 3.75 (48 to 57 by 3.25 to 4) μ .

Melilotus stem; culture 1 month old; conidia from pionnotes:

Conidia—

- 0-septate, 10 per cent.
- 1-septate, 35 per cent.
- 2-septate, 16 per cent.
- 3-septate, 32 per cent, 35 by 2.75 (30 to 41 by 2.75 to 3) μ .
- 4-septate, 3 per cent.
- 5-septate, 4 per cent.

Green bean pod; culture 10 days old; conidia from pionnotes:

Conidia—

- 0-septate, 61 per cent, 10 by 2.5 (8 to 14 by 2.25 to 2.75) μ .
- 1-septate, 17 per cent, 19 by 3 (15 to 22 by 2.75 to 3.25) μ .
- 2-septate, 6 per cent, 21 by 3.5 (20 to 23 by 3.25 to 3.5) μ .
- 3-septate, 15 per cent, 25 by 3.5 (18 to 36 by 3.25 to 3.5) μ .
- 4-septate, 1 per cent, 27 by 3.5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 31 per cent, 32 by 3.5 (18 to 50 by 2.75 to 4) μ .
- 4-septate, 2 per cent, 38 by 3.5 (27 to 50 by 3.25 to 4) μ .
- 5-septate, 2 per cent, 50 by 3.5 (43 to 55 by 3.25 to 4) μ .

FUSARIUM MONILIFORME Sheldon var. MAIUS Wollenweber and Reinking. Plate 1, fig. 11; Plate 6; text fig. 20.

Fusarium moniliforme maius WOLLENWEBER and REINKING, Phytopath. 15 (1925) 163.

Differs from the type by longer macroconidia, 3- to 5- (6-) septate; 3-septate, 28 to 48 by 2.25 to 3.5 μ ; 4-septate, 44 to 64 by 2.25 to 3.25 μ ; 5-septate, 54 to 76 by 2.5 to 3.25 μ ; 6-septate, 61 to 92 by 2.5 to 3.25 μ ; microconidia in chains, unicellular, 4 to 16 by 2 to 4 μ ; rarely 1-septate, 14 to 21 by 2.5 to 3.5 μ ; chlamydospores absent; sclerotia dark blue.

Habitat.—On dead peduncle and leaves of banana (*Musa sapientium* Linnæus). Tela, Honduras, Central America (*Reinking R 57*).

GROWTH ON VARIOUS MEDIA

The growth and color characters on the various media are similar to those of *F. moniliforme*.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 16 days old; conidia from pionnotes:

Conidia—

0-septate, 35 per cent, 8 by 2.75 (5 to 12 by 1.75 to 4.5) μ .

1-septate, 3 per cent, 16 by 3 (12 to 23 by 2.75 to 3.5) μ .

2-septate.

3-septate, 12 per cent, 42 by 3 (37 to 48 by 2.75 to 3.5) μ .

4-septate, 16 per cent, 46 by 2.75 (44 to 49 by 2.75) μ .

5-septate, 29 per cent, 57 by 2.75 (54 to 61 by 2.75 to 3.25) μ .

6-septate, 5 per cent, 64 by 2.75 (61 to 66 by 2.75) μ .

Hard potato agar; culture 70 days old; conidia from pionnotes:

Conidia—

0-septate, 65 per cent, 8 by 2.5 (4 to 20 by 2.25 to 4.5) μ .

1-septate, 4 per cent, 13 by 3 (10 to 17 by 2.75 to 3.5) μ .

2-septate.

3-septate, 13 per cent, 35 by 3.25 (21 to 39 by 3.25) μ .

4-septate, 13 per cent.

5-septate, 5 per cent.

Melilotus stem; culture 18 days old; conidia from sporodochia:

Conidia—

0-septate, 3 per cent, 10 by 2.75 (6 to 15 by 2 to 3.5) μ .

1-septate, 2 per cent, 19 by 3 (13 to 25 by 2.5 to 3.75) μ .

2-septate.

3-septate, 79 per cent, 39 by 2.75 (25 to 54 by 2.25 to 3) μ .

4-septate, 12 per cent, 62 by 2.75 (60 to 64 by 2.5 to 3) μ .

5-septate, 2 per cent, 69 by 2.75 (62 to 76 by 2.5 to 3.25) μ .

6- to 7-septate, 2 per cent, 79 by 2.75 (67 to 92 by 2.5 to 3.25) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 0-septate, 34 per cent, 9 by 2.75 (4 to 16 by 2 to 4) μ .
 1-septate, 3 per cent, 16 by 3 (14 to 21 by 2.5 to 3.5) μ .
 3-septate, 35 per cent, 39 by 3 (28 to 48 by 2.25 to 3.5) μ .
 4-septate, 14 per cent, 54 by 2.75 (44 to 64 by 2.25 to 3.25) μ .
 5-septate, 12 per cent, 63 by 2.75 (54 to 76 by 2.5 to 3.25) μ .
 6-septate, 2 per cent, 71 by 2.75 (61 to 92 by 2.5 to 3.25) μ .

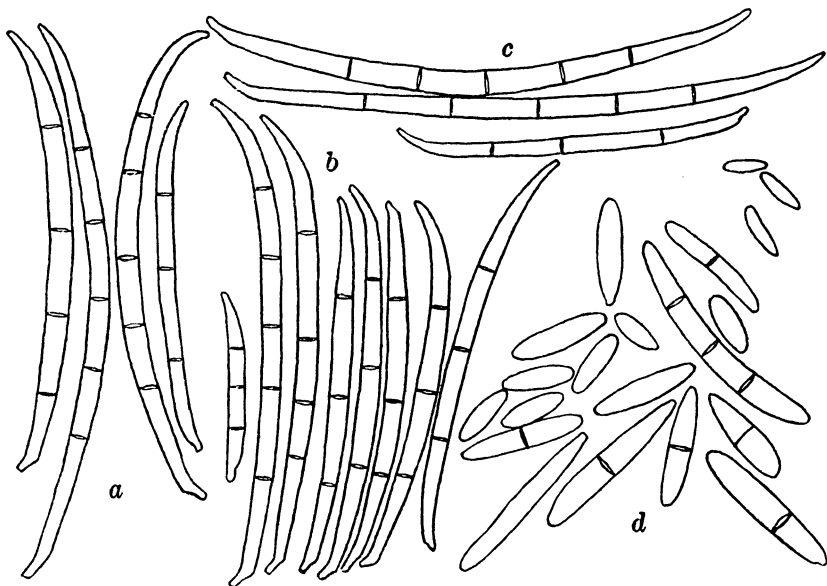


FIG. 20. *Fusarium moniliforme* Sheldon var. *maius* Wollenweber and Reinking; a, conidia, long, typical type, from pionnotes of 11-day-old hard potato-agar culture; b, conidia from sporodochia of 16-day-old *Melilotus*-stem culture; c, conidia from pionnotes of 11-day-old hard potato-agar culture; d, microconidia from pionnotes and mycelium of 11-day-old hard potato-agar culture.

FUSARIUM NEOCERAS Wollenweber and Reinking. Text fig. 21.

Fusarium neoceras WOLLENWEBER and REINKING, *Phytopath.* 15 (1925) 164.

Microconidia scattered or in false heads, not in chains, unicellular, ovoid fusoid, 9 to 12 by 3 to 3.5 (5 to 18 by 2.75 to 4.5) μ ; rarely 1-septate, 19 to 26 by 3.5 to 4.5 (14 to 34 by 3.25 to 5.5) μ ; macroconidia in sporodochia, but mostly in pionnotes, elongate, slightly curved, attenuate, subpedicellate, slightly constricted at the top, 3- to 5-septate, 38 to 68 by 4 to 5 (30 to 95 by 3.5 to 5.5) μ ; 3-septate, 32 to 59 by 3 to 5.5 μ ; 4-septate, 30 to 63 by 4 to 5.5 μ ; 5-septate, 55 to 67 by 4.5 to 5.5 μ ;

very seldom 6- to 9-septate, 51 to 120 by 4 to 5 μ ; chlamydospores and sclerotia absent; stroma sometimes violet.

Habitat.—On dead floral bracts of banana (*Musa sapientium* Linnæus) (R 149) and in the soil. Tela, Honduras, Central America (Reinking R 149).

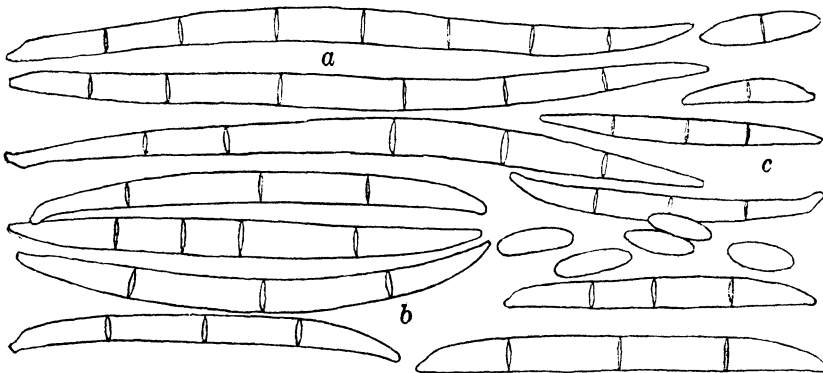


FIG. 21. *Fusarium neoceras* Wollenweber and Reinking; a, conidia from mycelium of 6-day-old hard potato-agar culture; b, conidia from mycelium of 20-day-old potato-tuber plug culture; c, macroconidia and microconidia from thin pionnotes of 37-day-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 4 to 12 days old have a dense mycelium with coarse mycelial strands standing out from the mass. The aërial mycelium is white and ivory yellow and pinkish buff with a stroma over the agar that is blackish violet. Dark hyssop violet concentric rings may appear at first on the agar about the point of transfer. Older cultures, up to 3.5 months old, have a dense aërial mycelium, with coarse mycelial strands, that is cartridge buff with deep slate brown concentric rings in agar or a blackish violet stroma. A cream buff pionnotes is usually produced. On potato agar plates 2 months old a medium scant, zonate, pale pinkish buff, aërial mycelium is present. Concentric rings of pale pinkish buff and hyssop violet are usually present.

Oat agar.—Cultures 24 days old are characterized by having a dense, thick, and matted mycelium that is white at the tips, but chiefly petunia violet and nigrosin violet.

Rice.—Cultures 21 days old have a dense, matted mycelium that is dull dark purple, dull dusky purple, with spinel red and Indian lake in the center and auricula purple and dusky auricula

purple at the base. Two-month-old cultures are matted and leathery with dark nigrosin violet at the top, and lower down dahlia carmine, dark maroon-purple, and dark perilla purple.

Potato-tuber plug.—Cultures 25 days old have a dense, matted, white, petunia violet, dark violet, raisin purple, and deep delft blue mycelium. Older cultures, 80 days old, have a thin matted and leathery mycelium that is dusky dull bluish green, dark delft blue, blackish violet, and blue-violet-black. A vinaceous buff and deep olive buff pionnotes is developed.

Melilotus stem.—Cultures 2 months old are characterized by a thick, dense, matted, pale pinkish buff, yellow ocher, and Dresden brown mycelial mass.

Mature corn stalk.—Cultures 1 month old have a medium dense and fluffy mycelium that is petunia violet, Bradley's violet, and dark vinaceous.

Banana peel.—Cultures 26 days old have a scant Mathews' purple mycelium.

Green bean pod.—Cultures 30 to 45 days old have a medium scant, cottony to leathery, cartridge buff, pale pinkish buff, petunia violet, and nigrosin violet mycelium. A cream buff and later dark olive buff pionnotes is produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; cultures 6 days old; conidia from mycelium and pionnotes:

Conidia—

0-septate, 12 per cent, 12 by 2.75 (7 to 16 by 2.75 to 3) μ .

1-septate, 6 per cent.

2-septate.

3-septate, 48 per cent, 46 by 3.5 (37 to 54 by 3 to 4) μ .

4-septate, 12 per cent, 59 by 4.5 (51 to 63 by 4.25 to 5) μ .

5-septate, 20 per cent, 63 by 3.75 (60 to 67 by 3.25 to 4) μ .

6-septate, 1 per cent.

7-septate.

8-septate.

9-septate, 1 per cent, 94 by 4.5 (67 to 120 by 4 to 5) μ .

Hard potato agar; culture 11 days old; conidia from pionnotes:

Conidia—

0-septate, 10 per cent, 11 by 2.75 (9 to 14 by 2.75 to 3.25) μ .

1-septate, 28 per cent, 24 by 3.5 (23 to 26 by 3.25 to 3.5) μ .

2-septate.

3-septate, 56 per cent, 53 by 4.75 (34 to 59 by 3.5 to 5.5) μ .

4-septate, 4 per cent, 58 by 4.75 (54 to 63 by 4.5 to 5.5) μ .

5-septate, 2 per cent, 61 by 5 (55 to 67 by 4.5 to 5.5) μ .

Hard potato agar; culture 18 days old; conidia from mycelium and pionnotes:

Conidia—

- 0-septate, 57 per cent, 12 by 3.5 (6 to 18 by 2.75 to 4.5) μ .
- 1-septate, 11 per cent, 21 by 4 (14 to 26 by 3.25 to 5.5) μ .
- 2-septate, 2 per cent, 36 by 5 μ .
- 3-septate, 29 per cent, 44 by 4.5 (34 to 54 by 4 to 5) μ .
- 4-septate, 1 per cent, 61 by 4.5 μ .

Green bean pod; culture 10 days old; conidia from pionnotes:

Conidia—

- 0-septate, 37 per cent, 12 by 3 (10 to 16 by 2.75 to 3.25) μ .
- 1-septate, 19 per cent, 19 by 3.5 (15 to 21 by 3.25 to 4) μ .
- 2-septate, 3 per cent, 27 by 3.5 (23 to 32 by 3.25 to 4) μ .
- 3-septate, 28 per cent, 38 by 4 (32 to 46 by 3.5 to 4.5) μ .
- 4-septate, 13 per cent, 46 by 4 (30 to 57 by 3.5 to 4.5) μ .

Green bean pod; culture 16 days old; conidia from mycelium and pionnotes:

Conidia—

- 0-septate, 38 per cent, 9 by 3 (6 to 12 by 2.75 to 3.25) μ .
- 1-septate, 13 per cent, 26 by 4.5 (18 to 34 by 4.5 to 5) μ .
- 2-septate, 4 per cent, 32 by 5 (29 to 36 by 5) μ .
- 3-septate, 45 per cent, 48 by 4.75 (36 to 59 by 4.5 to 5.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 0-septate, 31 per cent, 11 by 3 (5 to 18 by 2.75 to 4.5) μ .
- 1-septate, 14 per cent, 23 by 3.75 (14 to 34 by 3.25 to 5.5) μ .
- 2-septate, 2 per cent, 31 by 4.25 (23 to 36 by 3.25 to 5) μ .
- 3-septate, 41 per cent, 46 by 4.25 (32 to 59 by 3.5 to 5) μ .
- 4-septate, 6 per cent, 56 by 4.5 (30 to 63 by 4 to 5.5) μ .
- 5-septate, 4 per cent, 62 by 4.25 (55 to 67 by 4.5 to 5.5) μ .
- 6- to 9-septate, 2 per cent, 94 by 4.5 (67 to 120 by 4 to 5) μ .

The various strains of *Liseola* herein described are widespread throughout banana plantations, being present on decaying plant trash of different kinds and on living parts of plants. The parasitic nature of the different strains has not been carefully tested.(7)

IX. Section LATERITIUM Wollenweber

Lateritium WOLLENWEBER, Ann. Myc. 15 (1917) 54.

Mycelium white, rosy, yellow, sometimes carmine, aërial or immersed; chlamydospores frequently intercalary, but terminal always lacking; sclerotia knotty rugulose, sometimes dark blue; stroma spread out, erumpent; conidia spindle- to sickle-shaped, dorsiventral difference in curvature more conspicuous toward the apex, constricted at both ends or even pedicellate at the base, resembling the section *Elegans*, in tuberculate sporodochia often in long columns protruded, in pionnotes or scattered in

aërial mycelium. Imperfect stage of a *Gibberella*. Color type similar to that for the section *Elegans*, and sometimes to that for *Discolor*.

FUSARIUM FRUCTIGENUM Fries var. **MAIUS** Wollenweber forma 1 Wollenweber and Reinking. Plate 2, fig. 1; text fig. 22.

Fusarium fructigenum maius forma 1 WOLLENWEBER and REINKING, Phytopath. 15 (1925) 165.

Conidia in sporodochia and pionnotes, orange, spindle-shaped, dorsiventral difference in curvature more conspicuous toward the top cell than in the middle, constricted at both ends or even pedicellate at the base, 5- (3- to 6-) septate;

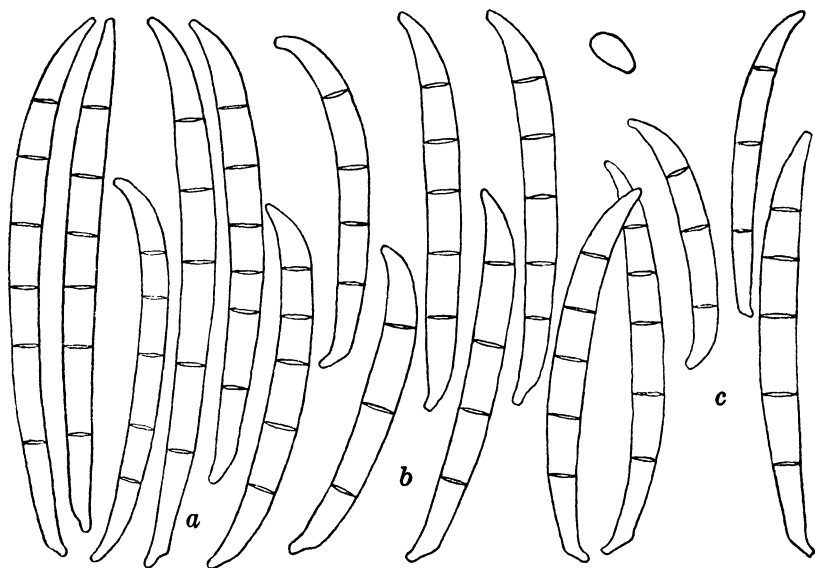


FIG. 22. *Fusarium fructigenum* Fries var. *maius* Wollenweber forma 1 Wollenweber and Reinking; a, conidia from pionnotes of 1-month-old rice culture; b, conidia from pionnotes of 17-day-old oatmeal-agar culture; c, conidia from sporodochia of 14-day old *Melilotus*-stem culture.

5-septate, 48 to 64 by 3.5 to 4.5 μ ; 6-septate, 63 to 80 by 3.5 to 4.75 μ ; 3-septate, 34 to 44 by 3.5 to 4.5 μ ; chlamydospores seldom present; sclerotia 1.5 mm in diameter, dark blue or ochraceous white; stroma carmine, differs from the type by the carmine color of the stroma.

Habitat.—On undetermined dead plant. Jamaica (Hansford 16, R 235).

The fungus was not isolated by Reinking, but was obtained through the courtesy of Mr. C. G. Hansford, of Jamaica.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Three-month-old cultures have a scant, white, aërial mycelium. A thick, pale pinkish buff and pinkish buff pionnotal growth is produced over the slant.

Oat agar.—Cultures 1 month old are characterized by a scant, white, aërial mycelium. A pionnotes, made up of small sporodochia, is produced over the slant. The sporodochia may be in concentric rings and vinaceous tawny. The stroma and agar at the base of the slant usually Indian red and Prussian red in places.

Rice.—Cultures 23 days old are medium scant, pale vinaceous pink on top, and on sides have a dark vinaceous mycelium. An apricot buff pionnotes is produced over the rice.

Potato-tuber plug.—Cultures 2 months old have a thin, matted, pale pinkish buff and pinkish buff mycelium over the plug. Small pale pinkish buff, pinkish buff, and dusky dull bluish green sclerotia are produced in places. A pinkish cinnamon pionnotes may be present.

Melilotus stem.—Cultures 1 month old have a scant, pinkish buff mycelium on top of the stem and vinaceous cinnamon sporodochia and pionnotes masses over the sides.

Alnus stem.—Cultures 1 month old are characterized by a scant, pinkish buff mycelium on top of the stem and small light pinkish cinnamon sporodochia scattered over the sides.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Oat agar; culture 12 days old; conidia from pionnotes:

Conidia—

3-septate, 8 per cent, 39 by 4.25 (34 to 44 by 4 to 4.5) μ .

4-septate, 24 per cent, 49 by 4.25 (46 to 52 by 4 to 4.5) μ .

5-septate, 68 per cent, 51 by 4.5 (47 to 54 by 4 to 5) μ .

Melilotus stem; culture 15 days old; conidia from sporodochia and pionnotes:

Conidia—

3-septate, 9 per cent, 43 by 3.75 (42 to 44 by 3.75 to 4) μ .

4-septate, 27 per cent, 58 by 4 (46 to 59 by 4 to 4.25) μ .

5-septate, 64 per cent, 58 by 4.25 (50 to 65 by 3.5 to 4.5) μ .

Rice; culture 1 month old; conidia from pionnotes:

Conidia—

3-septate, 6 per cent, 41 by 4 (38 to 44 by 3.5 to 4.5) μ .

4-septate, 14 per cent, 51 by 4.25 (46 to 55 by 4 to 4.5) μ .

5-septate, 71 per cent, 63 by 4.25 (50 to 75 by 4 to 4.5) μ .

6-septate, 9 per cent, 72 by 4 (63 to 80 by 3.5 to 4.75) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 8 per cent, 41 by 4 (34 to 44 by 3.5 to 4.5) μ .
 4-septate, 22 per cent, 53 by 4.25 (46 to 59 by 4 to 4.5) μ .
 5-septate, 67 per cent, 56 by 4 (48 to 64 by 3.5 to 4.5) μ .
 6-septate, 3 per cent, 72 by 4 (63 to 80 by 3.5 to 4.75) μ .

XI. Section SPICARIOIDES (Wollenweber subsection) Wollenweber, Sherbakoff, Reinking, Johann, and Bailey

Spicarioides WOLLENWEBER, Ber. der Deutsch. Bot. Gesell. 35 (1918) 741; WOLLENWEBER, SHERBAKOFF, REINKING, JOHANN, and BAILEY, Journ. Agr. Research 30 (1925) 841.

Stroma spread out, closely matted, carmine and pale pinkish cinnamon, aërial mycelium, floccose, from white to rose color; macroconidia resembling those in the section *Discolor* in sporodochia and pionnotes, ochraceous, elongate, pluriseptate, pedicellate, constricted at top end; microconidia in *Spicaria*-like chains; chlamydospores absent. Color type, yellow ocher and cinnamon brown.

FUSARIUM DECEMCELLULARE Brick. Plate 2, fig. 2; text fig. 23.

Fusarium decemcellulare BRICK, Jahresber. Ver. f. Angew. Bot. (1908) 237; WOLLENWEBER, Ann. Myc. 15 (1917) 22; Ber. der Deutsch. Bot. Gesell. 35 (1918) 741.

The perfect stage of *F. decemcellulare* Brick, the only species known in this section, has been proved to be *Calonectria rigidiuscula* (Berkeley and Broome) Saccardo. (See Plate 5, figs. 1 to 4.)

Stroma spread out, closely matted, carmine and pale pinkish cinnamon, stroma sometimes erumpent, tubercularialike; aërial mycelium, floccose, from white to rose color; macroconidia in sporodochia, sometimes in columns, and pionnotes, ochraceous, elongate, pedicellate, constricted at top end, 6- to 9-septate, 56 to 94 by 5.5 to 8 μ , fewer 1-, 2-, 3-, 4-, 5-septate; 6-septate, 56 to 73 by 5.5 to 7.25 μ ; 7-septate, 60 to 83 by 5.5 to 7.25 μ ; 8-septate, 59 to 86 by 6.25 to 7.25 μ ; 9-septate (sometimes 75 per cent), 75 to 95 by 6.25 to 8 μ ; microconidia in *Spicaria*-like chains, unicellular 5 to 9 by 2.75 to 4.5 μ ; 1-septate, 12 to 17 by 4 to 4.5 μ ; chlamydospores absent.

Habitat.—On cacao twigs (*Theobroma cacao* Linnæus) affected with die-back. Panama (Dunlap 161, R 118).

The fungus was not isolated by Reinking, but was obtained from Dr. V. C. Dunlap, of Panama. Petch¹ regards *Spicaria*

¹ Ann. Roy. Bot. Gard. Peradeniya 6 (1916) 172; 7 (1920) 116.

colorans as the conidial stage of *Calonectria rigidiuscula* (Berkeley and Broome) Saccardo. Weese⁸ supports this opinion and has thrown further light upon the synonymy of this ascomycete. The conidial form is so characteristic that there cannot be any doubt in regarding it as identical with the *Calonectria*, if such conidia develop from spore cultures. This has been done by spores taken from perithecia occurring on dead branches of an unknown tree from Los Baños, Laguna Province, Phil-

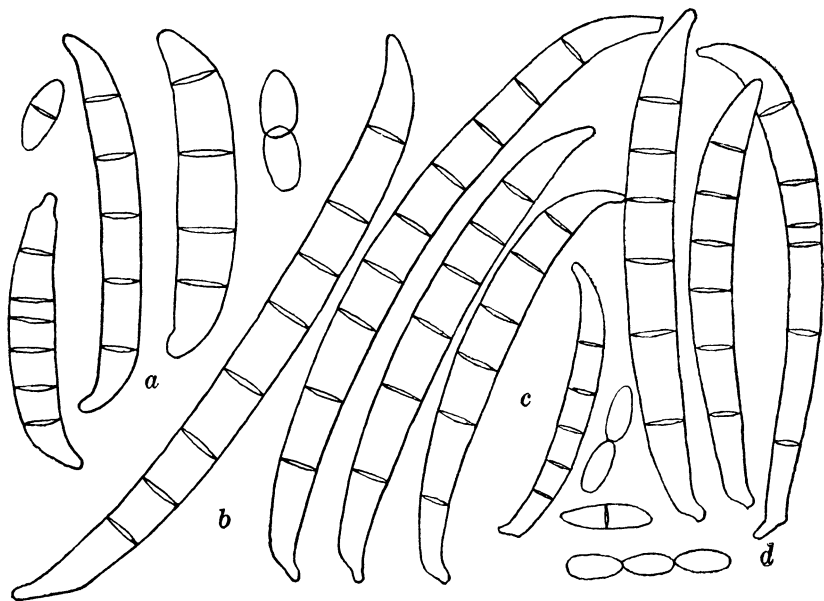


FIG. 23. *Fusarium decemcellulare* Brick; a, conidia, not typical and somewhat swollen, from pionnotes of 1-month-old green bean-pod culture; b, conidia, typical, from pionnotes of 4-day-old hard potato-agar culture; c, conidia, from sporodochia of 2-month-old hard potato-agar culture; d, microconidia, in chains, from mycelium of 2-month-old hard potato-agar plate culture.

ippine Islands. The material was sent by Julian Agati on the request of Reinking in 1925 and studied in Berlin by Wollenweber who, in reverse, succeeded in obtaining the perfect stage, not only in pure cultures of this strain, but from another one, collected and isolated from *Hibiscus sabdariffa* Linnæus by M. B. Schwarz, Buitenzorg, Java, and sent for determination in its *Fusarium* stage. These facts are regarded as sufficient proofs for the supposed identity, even if our strain from *Theobroma cacao* Linnæus, fully described in this paper, so far

⁸ Beitrag zur Kenntnis der Gattung *Calonectria*, Mitt. d. bot. Labor. d. Techn. Hochschule, Wien, Heft 2 (1924) 52-56.

has refused to produce perithecia. The synonymy of this fungus is as follows:

- Calonectria rigidiuscula* (Berkeley and Broome) Saccardo (1878) synonym *Calonectria sulcata* Starback (1899).
Calonectria meliae A. Zimmermann (1901).
Calonectria hibiscicola P. Hennings (1908).
Calonectria squamulosa Rehm (1913).
Calonectria tetraspora (Seaver) Saccardo (1913).
Scoleconectria tetraspora Seaver (1910).
Fusarium decemcellulare Brick (1908).
Spicaria colorans van Hall-de Jonge (1909).
Fusarium spicariae colorantis (van Hall-de Jonge) Saccardo and Trott. (1913).

Distribution on *Anona*, *Ficus pseudopalma*, *Hibiscus sabdariffa* and *schizopetalus*, *Melia azedarach*, *Theobroma cacao*, and other plants in the Tropics. Africa (Kamerun). America (Brazil, Surinam, Panama, Jamaica). Asia (Ceylon, Java, Philippine Islands).

Perithecia golden yellow, 0.4 to 0.7 by 0.25 to 0.4 mm, globose, rugose, gregarious; spores 3- (4 or 5-) septate, 23 to 30 by 6 to 8.5 μ , fusoid, slightly curved, rounded at both ends, light ocher in masses.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a medium thin, matted, pomegranate purple, rose pink, and rose red mycelium. Concentric lines of rose pink and rose red may be present. Older cultures, from 45 to 90 days of age, have a more-matted mycelium with irregular stromatic tufts, which is pomegranate purple with a Bordeaux ring at the base. The agar may be turned the same color in places. Large masses of warm buff and light orange yellow sporodochia and pionnotes are developed. Individual sporodochia may be produced in columns. Potato-agar plates 2 months old have a thin, closely matted, zonate mycelium that toward the edges of the plate is pinkish cinnamon and in the center spinel red. Buff yellow sporodochia and pionnotes masses are scattered over the plate.

Oat agar.—Cultures 21 days old have a closely matted, spinel red and Indian lake mycelium over the slant. Dense masses of buff yellow pionnotes and a few individual sporodochia are present.

Rice.—Cultures 20 days old are characterized by a medium scant, chiefly yellow ocher, and in a few places pomegranate purple mycelium, leathery in places. Pionnotal masses are pres-

ent over the rice. Two-month-old cultures have a more or less powdery mycelium that is yellow ochre with touches of ochraceous orange and cinnamon brown. Light buff, light brownish olive, and Isabella color pionnotes masses are produced.

Potato-tuber plug.—Cultures 25 days old have a medium thick, dense, felty, La France pink mycelium, tufted in places, with light buff sporodochia just developing. Older cultures, 80 days old, are similar with an addition of Bordeaux red in places. The pionnotal masses are large and buff yellow or honey yellow. Sporodochia in columns may also be present.

Melilotus stem.—Cultures 2 months old have a medium dense, closely matted, pale pinkish cinnamon mycelium over the stem. Pinkish buff and pinkish cinnamon sporodochia and pionnotes masses are produced.

Alnus stem.—Cultures 21 days old have a very scant aërial mycelium on the top of the twig. Pale pinkish cinnamon and pale pinkish buff sporodochia are formed from the lenticels in the twig.

Banana peel.—Cultures 38 days old have a scant, pale pinkish buff and pinkish buff mycelium. Cream buff and chamois sporodochia are developed.

Green bean pod.—Cultures 50 days old are characterized by a medium thin, matted mycelium that is cartridge buff, pale cinnamon pink, pale pinkish buff with spots of rose color. A cinnamon buff stroma erumpent may be present in a few places. Cinnamon buff and cinnamon pionnotes masses and sporodochia are produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 18 days old; conidia from mycelium and pionnotes:

Conidia—

- 0-septate, 52 per cent, 8 by 4 (5 to 9 by 3.25 to 4.5) μ .
- 1-septate, 17 per cent, 12 by 4.25 (10 to 18 by 3.5 to 4.5) μ .
- 2-septate, 5 per cent, 24 by 5.5 (22 to 27 by 5.25 to 6) μ .
- 3-septate, 5 per cent, 32 by 5.5 (30 to 36 by 5.5) μ .
- 4-septate, 4 per cent, 35 by 5.5 (33 to 36 by 5.5) μ .
- 5-septate, 9 per cent, 54 by 6.25 (42 to 68 by 5.5 to 7.25) μ .
- 6-septate, 5 per cent, 62 by 6.5 (57 to 68 by 6.25 to 7.25) μ .
- 7-septate, 3 per cent, 74 by 6.5 (70 to 81 by 6.25 to 7.25) μ .

Hard potato agar; culture 32 days old; conidia from sporodochia:

Conidia—

- 0-septate, 13 per cent, 7 by 4 (6 to 8 by 3.5 to 4.5) μ .
- 1-septate.
- 2-septate.
- 3-septate, 2 per cent, 25 by 4.5 μ .

4-septate, 2 per cent, 38 by 5 μ .

5-septate, 8 per cent, 59 by 6 (45 to 71 by 5.5 to 6.25) μ .

6-septate, 21 per cent, 66 by 6.25 (57 to 72 by 6.25) μ .

7-septate, 48 per cent, 70 by 6.25 (63 to 78 by 5.5 to 7.25) μ .

8-septate, 4 per cent, 72 by 6.25 (59 to 86 by 6.25) μ .

9-septate, 2 per cent, 78 by 6.25 (68 to 90 by 6.25) μ .

Green bean pod; culture 9 days old; conidia from sporodochia:

Conidia—

0-septate, 20 per cent, 7 by 3.25 (7 to 8 by 2.75 to 3.5) μ .

1-septate, 1 per cent, 17 by 4.5 μ .

2-septate.

3-septate.

4-septate, 3 per cent, 50 by 5.75 (41 to 59 by 5.5 to 6.25) μ .

5-septate, 4 per cent, 53 by 6 (52 to 54 by 6 to 6.25) μ .

6-septate, 41 per cent, 62 by 6.25 (56 to 73 by 5.5 to 7.25) μ .

7-septate, 15 per cent, 71 by 6.5 (60 to 83 by 5.5 to 7.25) μ .

8-septate, 6 per cent, 71 by 6.75 (59 to 78 by 6.25 to 7.25) μ .

9-septate, 10 per cent, 75 by 6.75 μ .

Water culture 21 days old; conidia from sporodochia:

Conidia—

6-septate, 1 per cent.

7-septate, 40 per cent.

8-septate, 27 per cent.

9-septate, 31 per cent.

10-septate, 1 per cent.

11- to 12-septate, rare.

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

6-septate, 17 per cent, 63 by 6.25 (56 to 73 by 5.5 to 7.25) μ .

7-septate, 27 per cent, 72 by 6.25 (60 to 83 by 5.5 to 7.25) μ .

8-septate, 12 per cent, 72 by 6.5 (59 to 86 by 6.25 to 7.25) μ .

9-septate, 14 per cent, 77 by 6.5 (75 to 90 by 6.25 to 6.75) μ .

XII. Section SAUBINETII Wollenweber

Saubinetii WOLLENWEBER, Ann. Myc. 15 (1917) 2; WOLLENWEBER and REINKING, Phytopath. 15 (1925) 165.

Stroma spread out, floccose or dense, ochraceous, carmine; aerial mycelium from white to rose color; conidia scattered in sporodochia or in pinnotes, from pale orange to ochraceous, sickle-shaped, elongate, 3- to more-septate, constricted at top end, pedicellate at base, sometimes apedicellate; chamydospores absent. Some species have a perfect stage that is a *Gibberella* of the section *Saubinetii*.

FUSARIUM MACROCERAS Wollenweber and Reinking. Plate 2, fig. 3; text fig. 24.

Fusarium macroceras WOLLENWEBER and REINKING, Phytopath. 15 (1925) 166.

Stroma floccose, rose white, or dense plectenchymic, yellow, ochraceous, and carmine; conidia scattered, lanceolate or sickle-

shaped, dorsiventral, constricted at the top end, conical at the base, apedicellate, conidia in sporodochia and pionnotes, elongate, slightly sickle-shaped, attenuated at both ends, pedicellate, 5- to 7-septate, 47 to 64 by 4.5 to 5.75 (35 to 74 by 4 to 7) μ , fewer 1- to 4- or 8- or 9-septate, very seldom 14-septate, 150 by 6.25 μ ; chlamydospores absent.

Habitat.—On mature bush-bean pods (*Phaseolus vulgaris* Linnaeus). Tela, Honduras, Central America (Reinking R 95).

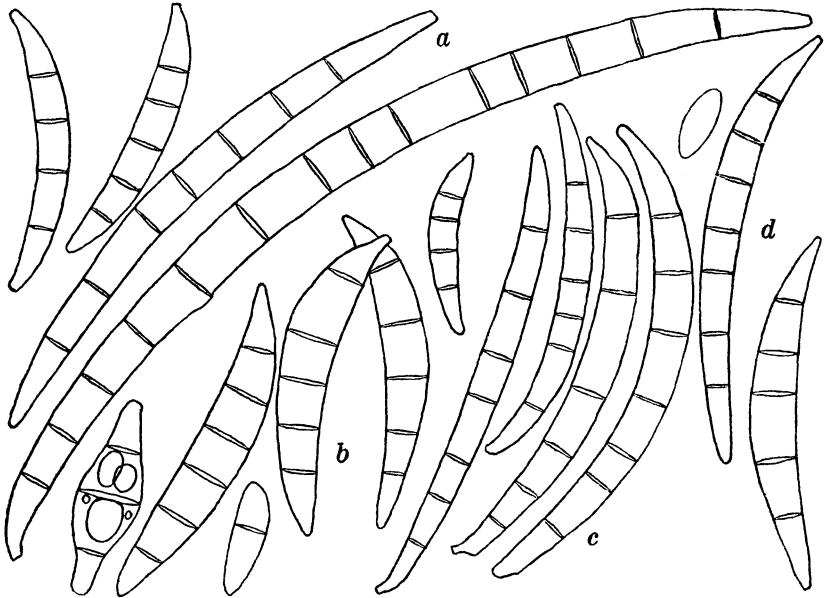


FIG. 24. *Fusarium macroceras* Wollenweber and Reinking; a, conidia, few abnormally large, from mycelium of 3-day-old oatmeal-agar culture; b, conidia, short and broad type, from mycelium of 2-month-old potato-tuber plug culture; c, conidia, typical long and slender type, from mycelium of 2-month-old hard potato-agar culture; d, conidia from mycelium of 19-day old *Alnus*-stem culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 5 days old are characterized by thin, matted, powdery and, in places, somewhat tufted mycelium that is white at the tips and pomegranate purple over the agar. Few spots of cinnamon brown may be present. Older cultures, up to 3 months of age, usually have a dense, matted, pale pinkish buff and spinel pink mycelium. The agar may be turned pomegranate purple and Bordeaux. Few cream buff pionnotes masses may be produced. On plates 2 months old a medium dense, seashell pink aerial mycelium is found. In the substra-

tum concentric rings of seashell pink and spinel red mycelium are developed.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 to 2 months old are characterized by a thick, dense, matted, pale flesh color, cameo pink, and spinel red aërial mycelium. In the substratum the mycelium is Bordeaux. A pomegranate purple stroma may be produced in places on the agar.

Oat agar.—Cultures 1 month old have a thick, dense mycelium that is white and pomegranate purple and Bordeaux at the edges of the growth. Dense, salmon color masses of pionnotes may be produced in places over the slant.

Rice.—Cultures 19 days old have a matted mycelium that is yellow ocher on the glass and over the rice, and Dresden brown to mummy brown in places. Pomegranate purple spots may be found. Older cultures, 2 months of age, are characterized by a matted, yellow ocher, buckthorn brown, and Dresden brown mycelium. Spots of olive ocher and pinkish buff may be present on the sides.

Potato-tuber plug.—Cultures 1 month old have a fluffy mycelium above and thick matted below that is seashell pink, pomegranate purple with Saccardo's umber here and there. Older cultures, 80 days old, are characterized by a matted and leathery mycelium that is pale pinkish buff and pomegranate purple with Bordeaux below on the cylinder.

Melilotus stem.—Cultures 2 months old have a thick, dense, matted, pale pinkish buff mycelium.

Alnus stem.—Cultures 1 month old have a medium scant, fine, white and light ochraceous buff mycelium here and there over the twig.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 32 days old; conidia from mycelium and pionnotes:

Conidia—

- 0-septate, 3 per cent, 5 by 1.75 (5 by 1.25 to 2.25) μ .
- 1-septate, 1 per cent, 23 by 4.5 μ .
- 2-septate, 1 per cent, 32 by 4.5 μ .
- 3-septate, 6 per cent, 34 by 4.25 (27 to 40 by 4 to 4.5) μ .
- 4-septate, 23 per cent, 43 by 5 (36 to 49 by 4 to 7) μ .
- 5-septate, 28 per cent, 47 by 5.75 (35 to 67 by 5 to 7) μ .
- 6-septate, 28 per cent, 52 by 6.25 (46 to 58 by 5.5 to 7) μ .
- 7-septate, 8 per cent, 60 by 6.25 (57 to 75 by 5.5 to 6.75) μ .
- 8-septate, 1 per cent, 66 by 6.25 μ .
- 9-septate, 1 per cent, 59 by 5.5 μ .

Potato-tuber plug; culture 2 months old; conidia from mycelium and pionnotes:

Conidia—

- 1-septate, 1 per cent.
- 2-septate, 1 per cent.
- 3-septate, 5 per cent, 29 by 6.25 (26 to 33 by 5.5 to 7) μ .
- 4-septate, 14 per cent, 35 by 7 μ .
- 5-septate, 25 per cent, 45 by 5.25 (42 to 48 by 3.5 to 7) μ .
- 6-septate, 20 per cent, 48 by 4.75 (45 to 51 by 4 to 5.5) μ .
- 7-septate, 20 per cent, 64 by 4.5 μ .
- 8-septate, 9 per cent, 60 by 5 μ .
- 9-septate, 4 per cent, 79 by 4.25 (73 to 85 by 4 to 4.5) μ .
- 10-septate, 1 per cent, 63 by 7 μ .

Oat agar; culture 3 days old; conidia from pionnotes:

Conidia—

- 4-septate, 2 per cent, 38 by 4 μ .
- 5-septate, 17 per cent, 46 by 5 μ .
- 6-septate, 12 per cent.
- 7-septate, 33 per cent, 79 by 5.25 μ .
- 8-septate, 12 per cent.
- 9-septate, 13 per cent.
- 10-septate, 9 per cent.
- 11-septate, 1 per cent, 93 by 5 μ .
- 14-septate, 1 per cent, 130 by 6.25 μ .

Alnus stem; culture 19 days old; conidia from mycelium:

Conidia—

- 4-septate, 3 per cent.
- 5-septate, 27 per cent, 47 by 6.25 μ .
- 6-septate, 31 per cent.
- 7-septate, 24 per cent, 61 by 5.5 (57 to 65 by 4.75 to 6.5) μ .
- 8-septate, 9 per cent.
- 9-septate, 6 per cent, 78 by 5.5 μ .
- 10-septate, rare, 70 by 5.75 μ .
- 11-septate, rare, 80 by 6.5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

- 5-septate, 24 per cent, 46 by 5.5 (35 to 67 by 3.5 to 7) μ .
- 6-septate, 23 per cent, 50 by 5.5 (45 to 58 by 4 to 7) μ .
- 7-septate, 21 per cent, 66 by 6.25 (57 to 79 by 4.5 to 6.75) μ .

XIII. Section ELEGANS Wollenweber

Elegans WOLLENWEBER, Phytopath. 3 (1913) 28; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 202; WOLLENWEBER, Ber. der Deutsch. Bot. Gesell. 35 (1918) 741.

Microconidia usually simple, 5 to 12 by 2 to 3.5 μ ; macroconidia free, in tubercular sporodochia or confluent pionnotes, straight in some species, more or less sickle-shaped in others, end cells more curved than those in the center, from acuminate to constricted, base more or less pedicellate; blue sclerotia, formed

in many species. This section, otherwise very much like *Lateritium*, differs from the latter by having a large number of microconidia and terminal chlamydospores. Color type, vinaceous to violet. Many of these fungi cause wilt diseases; some of them also cause rots on various parts of cultivated plants.

1. Subsection **ORTHOCERA** Wollenweber

Orthocera WOLLENWEBER, Ann. Myc. 35 (1917) 2; Ber. der Deutsch. Bot. Gesell. 35 (1918) 741.

Sporodochia imperfect, usually absent, microconidia typically present. Conidia are nine to twelve times as long as thick.



FIG. 25. *Fusarium bostrycoides* Wollenweber and Reinking; a, conidia from mycelium of 23-day-old hard potato-agar culture; b, chlamydospores from mycelium of 23-day-old hard potato-agar culture; c, conidiophore, bostryxlike, from mycelium of 14-day-old *Melilotus*-stem culture, $\times 500$.

FUSARIUM BOSTRYCOIDES Wollenweber and Reinking. Text fig. 25.

Fusarium bostrycoides WOLLENWEBER and REINKING, Phytopath. 15 (1925) 166.

Stroma plectenchymic from brownish white to green or violet; aërial mycelium cæspitose, cream color; microconidia numerous, scattered, or in false heads, formed on verticillate or bostryxlike, branched conidiophores; unicellular, ovoid, 6 to 11 by 2.5 to 3.25 (4 to 13 by 2 to 4) μ ; very rarely 1-septate, 15 to 22 by 2.5 to 3.75 μ , and 3-septate, straight to slightly sickle-shaped, subpedicellate, 24 to 29 by 2.5 to 4 μ ; sporodochia and pionnotes absent; chlamydospores numerous, terminal and in-

tercalary, globose, unicellular or in chains, rugose, 6 to 8 μ in diameter.

Habitat.—In soil. Tela, Honduras, Central America (*Reinking R 169*).

The fungus on rice culture has a rosy acid modification of color, changing to blue by addition of sufficient alkali.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Culture 12 days old characterized by a scant, thin matted, tufted in places, cartridge buff and Saccardo's slate mycelium. Older cultures, from 1 to 3 months old, have a short, woolly, medium scant, thin matted, sometimes powdery mycelium that is cream color, cartridge buff, and cinnamon buff with deep slate olive at the base of the slant. Potato-agar plates 2 months old have a medium thin, short, woolly and powdery, zonate, pinkish buff mycelium over the plate.

Oat agar.—Cultures 15 days old have an aërial mycelium that is dense, matted, woolly, and powdery in places. It is pale pinkish buff, dark grayish lavender, slate violet⁽¹⁾ and slate blue with purplish vinaceous in places.

Rice.—Cultures 19 days old have a medium scant and matted, felty, white, dark vinaceous purple, neutral red, and dark Corinthian purple mycelium over the rice. The rice turns shrimp pink. Cultures 2 months old are characterized by a matted mycelium with a combination of neutral red, dark vinaceous purple, Indian lake, and cartridge buff above, and on the sides pale pinkish cinnamon and dark vinaceous brown. The rice is shrimp pink and hydrangea pink.

Potato-tuber plug.—Cultures 21 days old have a matted white and light buff mycelium. Older cultures, 80 days old, are characterized by a thin, matted, felty, and leathery mycelium that is pinkish buff and olivaceous black in places.

Melilotus stem.—Cultures 24 days old have a woolly, pinkish buff mycelium with powdery tufts in places over the stem.

MEASUREMENTS OF CONIDIA

Hard potato agar; cultures 23 days old; conidia from mycelium:

Conidia—

0-septate, 94 per cent, 9 by 3 (4 to 13 by 2 to 4) μ .

1-septate, 2 per cent, 19 by 3 (15 to 22 by 2.5 to 3.5) μ .

2-septate.

3-septate, 4 per cent, 27 by 3.25 (24 to 29 by 2.5 to 4) μ .

FUSARIUM ORTHOCERAS Appel and Wollenweber. Text fig. 26.

Fusarium orthoceras APPEL and WOLLENWEBER, Arb. Kais. Biol. Anst. Land- u. Forstw. 8 (1910) 141-156; WOLLENWEBER, Phytopath. 3 (1913) 30; Journ. Agr. Research 2 (1914) 263-264; LEWIS, Maine Agr. Exp. Sta. Bull. 219 (1913) 203-258; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 202-203; WOLLENWEBER, Ann. Myc. 15 (1917) 23.

Conidia as a rule unicellular, averaging 5 to 12 by 2.5 to 3.5 μ , embedded in a cottony mycelium layer, often jellied with age; sporodochia and pionnotes absent; sclerotia absent. A few, not exceeding 15 per cent, of the conidia may be 3-septate, 25 to 46 by 3 to 4 μ ; septal zone nearly cylindrical, slightly curved at the apical end, which is inequilateral-conical; base nearly straight-conical or appendicular, seldom subpedicellate, 4- and

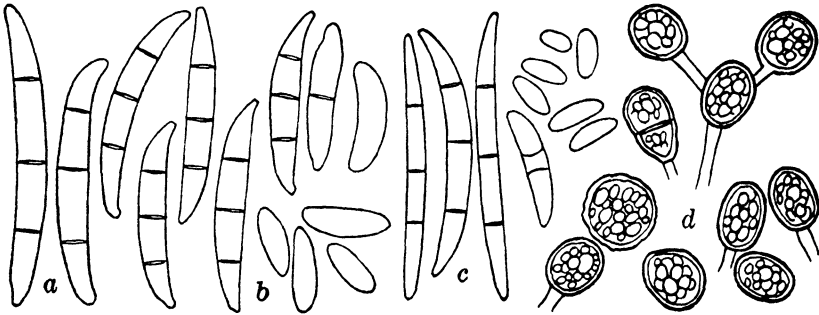


FIG. 26. *Fusarium orthoceras* Appel and Wollenweber; a, conidia from mycelium of 15-day-old hard potato-agar culture; b, conidia from mycelium of 14-day-old oatmeal-agar culture; c, conidia from mycelium of 2-month-old potato-tuber plug culture; d, chlamydospores from mycelium of 2-month-old hard potato-agar culture.

5-septate conidia rare, averaging up to 50 by 4 μ ; conidiophores with irregularly arranged sterigmata, seldom trifurcate. The fungus is ochreous to salmon color in light, in darkness it fades to brownish white. Thalloplectenchymata wine red in the acid modification (on rice) and blue spotted in the basic modification (on potato tubers); sclerotial plectenchymata entirely wanting. Chlamydospores intercalated, globose to ovoid, 1-celled forms averaging 7 to 10 μ , 2-celled forms rarer, but with a somewhat larger major longitudinal axis.

Habitat.—In soil. Tela, Honduras, Central America (*Reinking R 162*). On diseased cacao pod (*Theobroma cacao* Linnaeus) and in the soil. Jamaica (*Hansford 2 and 13, R 223 and 232*).

The parasitic nature of this fungus on bananas has not been carefully tested. (7) It is highly possible that *F. orthoceras* may

have some relation to banana-root troubles. It may also be the cause of a rot of potato tubers in the United States. A rot of apple and cucumber fruit is produced upon inoculation.(6)

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 14 days old are characterized by a fine, thick, matted mycelium that is white, ivory yellow, cream buff, sometimes with dark slate violet(1) concentric rings about the point of transfer on agar. Older cultures, between 1 and 3 months of age, are the same, but with an addition of cartridge buff, cream buff, chamois, and soft bluish violet. The mycelium may be matted, cottony, or gelatinous (self-digested). On potato-agar plates 2 months old a scant, pale pinkish buff mycelium is produced.

Potato agar, 5 per cent dextrose.—Cultures 1 month old had no aërial mycelium. The mycelium in the substratum was dark maroon-purple.

Oat agar.—Cultures 22 days old have a short, dense, matted, aërial mycelium, that is white and pale cinnamon pink with vinaceous and pinkish vinaceous on the sides at the base of the slant.

Rice.—Cultures 21 days old have a medium scant, thulite pink, spinel red, and light rosolane purple mycelium. Older cultures, from 1 to 2 months of age, are characterized by a leathery mycelium that ranges from dusky violet-blue (2) on top to dark dull bluish violet (3) and dusky dull violet (1) below. In places it may be cream buff, yellow ocher, and sayal brown. A slight benzolic odor is present.

Potato-tuber plug.—Cultures 22 days old have a medium dense, leathery, white and cream color mycelium, possibly with spots of dark chessylite blue or dark dull blue-violet in places. Older cultures, from 1 to 2 months old, have a thin, wet leathery, cream buff and chamois mycelium with Saccardo's slate in places.

Melilotus stem.—Cultures 1 month old have a medium scant, white and cinnamon buff mycelium over the stem.

Alnus stem.—Growth on *Alnus* is similar to that on *Melilotus*.

Mature corn stalk.—Cultures 54 days old have a medium dense, and in places a leathery mycelium that is cream buff, honey yellow, and pale olive buff.

Banana peel.—Cultures 26 days old have a medium scant, coarse, matted, wet in places, white, pale pinkish buff, or

cinnamon buff mycelium. Older cultures, up to 3 months of age, have a scant, white, cartridge buff, and pinkish buff mycelium. Patches of pale ochraceous buff and antimony yellow may appear where the mycelium touches the glass.

Banana fruit flesh.—Cultures 26 days old have a dense, and in places matted, white, light buff, and buckthorn brown mycelium.

Green bean pod.—Cultures 1 to 2 months old have a medium dense, cartridge buff, cream buff, light pinkish buff, pinkish buff, or pale cinnamon pink mycelium over the bean. It may be clay color where it touches the glass. Self digestion may also occur.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 30 days old; conidia from mycelium:

Conidia—

- 0-septate, 61 per cent, 9 by 3 (5 to 18 by 2.75 to 4.5) μ .
- 1-septate, 14 per cent, 14 by 3.5 (11 to 18 by 3.25 to 4.5) μ .
- 2-septate, 5 per cent, 20 by 4 (15 to 23 by 3.25 to 4.5) μ .
- 3-septate, 18 per cent, 32 by 3.75 (22 to 41 by 3.25 to 4.5) μ .
- 4-septate, 1 per cent, 33 by 4 μ .
- 5-septate, 1 per cent, 43 by 4.5 μ .
- 6-septate, rare, 47 by 5 μ .

Green bean pod; culture 1 month old; conidia from mycelium:

Conidia—

- 0-septate, 70 per cent, 8 by 3 (5 to 14 by 2.75 to 3.5) μ .
- 1-septate, 15 per cent, 17 by 3.5 (14 to 20 by 3.25 to 4) μ .
- 2-septate, 2 per cent, 20 by 3.5 (18 to 22 by 3.5) μ .
- 3-septate, 13 per cent, 28 by 3.75 (23 to 32 by 3.5 to 4.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

- 0-septate, 65 per cent, 9 by 3 (5 to 18 by 2.75 to 4.5) μ .
- 1-septate, 14 per cent, 15 by 3.5 (11 to 20 by 3.25 to 4.5) μ .
- 2-septate, 4 per cent, 20 by 3.75 (15 to 23 by 3.25 to 4.5) μ .
- 3-septate, 15 per cent, 30 by 3.75 (22 to 41 by 3.25 to 4.5) μ .

FUSARIUM ORTHOCERAS Appel and Wollenweber var. **TRISEPTATUM** Wollenweber.
Text fig. 27.

Fusarium orthoceras triseptatum WOLLENWEBER, Journ. Agr. Research
2 (1914) 264-267.

Differs from *Fusarium orthoceras* in having a higher septation of conidia, by the presence of sporodochia and a reduced pionnotes. Under normal conditions, as many as 100 per cent of the conidia are 3-septate; 10 per cent of 4- and 5-septate conidia are found; unicellular or small-septate conidia and chlamydospores occur and prevail under certain conditions.

Habitat.—On decaying bunch of bananas (*R* 45), in the interior of the pseudostem of a diseased banana plant (*Musa*

sapientium Linnæus), and in the soil. Tela and Trujillo, Honduras, Central America (*Reinking R 45*).

Soil inoculation about banana plants failed to produce infection.(7)

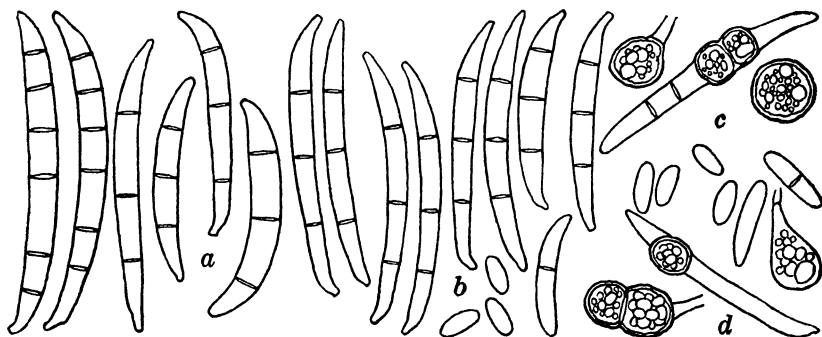


FIG. 27. *Fusarium orthoceras* Appel and Wollenweber var. *triseptatum* Wollenweber; a, conidia from mycelium of 16-day-old hard potato-agar culture; b, conidia from mycelium of 11-day-old hard potato-agar culture; c, chlamydospores from 32-day-old hard potato-agar culture; d, chlamydospores from 16-day-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 14 days old have a thin, cottony, and dense, matted, white, ivory yellow, and cream color mycelium. Older cultures, 1 to 3 months of age, are characterized by a white, cottony, and leathery, pale ochraceous buff, ivory yellow, and cream buff mycelium. A pale ochraceous buff, self-digested mass may be present.

Oat agar.—Cultures 1 month old have a medium dense, short, matted, pale pinkish cinnamon mycelium over the agar. A dull dusky purple stroma may be produced in places.

Rice.—Cultures 21 days old have a dense, matted, white, cameo pink, thulite pink, and spinel pink mycelium. Cultures 1 to 2 months old have a fluffy to leathery mycelium that is white, pinkish buff, cream color, thulite pink, and dark dull bluish violet.(1) The rice remains clear. A slight benzolic odor is present.

Potato-tuber plug.—Young cultures have a dense, matted, white mycelium. Cultures 81 days old are the same with an addition of cartridge buff and cream buff.

Melilotus stem.—Cultures 1 month old have a scant, pinkish buff, clay color, and tawny olive mycelium. The aërial mycelium may be self-digested. Cinnamon buff sporodochia are produced.

Alnus stem.—Cultures 1 month old have a medium scant, pinkish cinnamon and cinnamon mycelium over the top of the twig.

Mature corn stalk.—Cultures 1 month old have a scant, fluffy, white, aërial growth. At the age of 53 days the mycelium has changed to dark slate violet.⁽¹⁾

Banana peel.—Cultures 26 days old have a medium scant, matted, white mycelium; cream color, dark terre-verte, and mummy brown stromatic bodies may be produced.

Banana-fruit flesh.—Cultures 26 days old have a dense, matted, white mycelial growth.

Green bean pod.—Cultures 1 to 2 months old have a medium scant mycelium that is flattened over the bean and is cartridge buff and pale pinkish buff. The mycelium may be slimy or self digested, and olive buff with vinaceous buff. Cinnamon buff stromatic masses may be produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 40 days old; conidia from mycelium:

Conidia—

0-septate, 64 per cent, 10 by 3 (5 to 15 by 2.75 to 3.5) μ .

1-septate, 20 per cent, 16 by 3.5 (13 to 22 by 3.25 to 3.5) μ .

2-septate, 2 per cent, 25 by 3.5 (23 to 25 by 3.5) μ .

3-septate, 12 per cent, 36 by 3.5 (24 to 41 by 3.25 to 3.5) μ .

4-septate, 1 per cent, 41 by 3.5 (31 to 43 by 3.25 to 3.5) μ .

5-septate, 1 per cent, 38 by 4 (35 to 41 by 3.5 to 4) μ .

Green bean pod; culture 8 days old; conidia from mycelium:

Conidia—

0-septate, 44 per cent, 9 by 3 (5 to 14 by 2.75 to 3.5) μ .

1-septate, 19 per cent, 17 by 3.75 (14 to 22 by 3.5 to 4) μ .

2-septate, 1 per cent, 23 by 3.5 μ .

3-septate, 35 per cent, 32 by 4.25 (22 to 41 by 4 to 4.5) μ .

4-septate, 1 per cent, 40 by 4.5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

0-septate, 54 per cent, 9 by 3 (5 to 15 by 2.75 to 3.5) μ .

1-septate, 19 per cent, 16 by 3.5 (13 to 22 by 3.25 to 4) μ .

2-septate, 1 per cent, 24 by 3.5 (23 to 25 by 3.5) μ .

3-septate, 24 per cent, 34 by 3.75 (22 to 41 by 3.25 to 4.5) μ .

4-septate, 1 per cent, 40 by 4 (31 to 43 by 3.25 to 4.5) μ .

5-septate, 1 per cent, 40 by 4.5 (35 to 41 by 3.5 to 4) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Hard potato agar; culture 1 month old:

Chlamydospores—

0-septate, conidial, chlamydospores, 65 per cent, 7.25 by 7.75 (6.5 to 8.25 by 6 to 7.25) μ .

1-septate, conidial, chlamydospores, 35 per cent, 10 by 6 (9 to 11 by 5.5 to 6.5) μ .

2. Subsection CONSTRICTUM Wollenweber (sensu stricto)

Constrictum WOLLENWEBER, Ann. Myc. 15 (1917) 2 (excl. *F. moniliforme* Sheldon).

Sporodochia present. Conidia slender, narrow, constricted at top end, pedicellate chlamydospores common and typical. Type species, *F. batatatis* Wollenweber.

FUSARIUM BULBIGENUM Cooke and Massee. Text fig. 28.

Fusarium bulbigenum COOKE and MASSEE, Grevillea 16 (1887) 49; SACCARDO, Syll. Fung. 10 (1892) 725; MASSEE, Brit. Fung. Flor. 3 (1893) 482; Kew Bull. No. 8 (1913) 307-309; WOLLENWEBER, Jahresber. Ver. f. Angew. Bot. 14 (1916) 2, 125; Ann. Myc. 15 (1917) 23.

Mycelium effused, white and cartridge buff, stroma occasionally violet, at first somewhat erumpent in small tufts and later confluent. Microconidia unicellular, 9 to 10 by 2.75 to 3.5 μ ; 1-septate, 14 to 21 by 2.75 to 3.5 μ in abundance in aërial mycelium

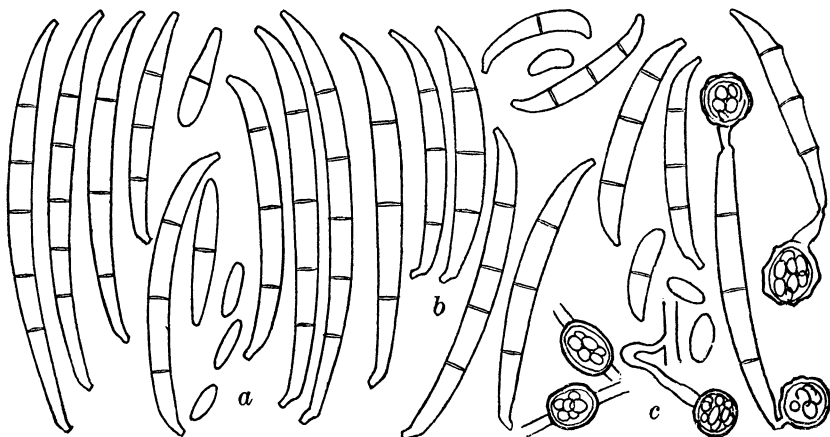


FIG. 28. *Fusarium bulbigenum* Cooke and Massee; a, conidia from mycelium and pionnotes of 16-day-old oatmeal-agar culture; b, conidia from minute sporodochia of 14-day-old *Alnus*-stem culture; c, chlamydospores from mycelium of 15-day-old oatmeal-agar culture and from minute sporodochia of 14-day-old *Alnus*-stem culture.

and often prevailing. Pionnotes ochraceous salmon or warm buff; develops the typical long conidia, fusiform arcuate or incurved at the acute extremities, more or less pedicellate at the base; 3-septate, 26 to 50 by 2.75 to 4 μ ; rarely 4- to 5-septate; 4-septate, 33 to 52 by 2.75 to 4 μ ; 5-septate, 41 to 56 by 2.75 to 3.75 μ .

Chlamydospores common, terminal and intercalary, 5 to 9 μ in diameter.

Habitat.—On cut surface of banana rhizome (*Musa sapientium* Linnæus) (R 49) and in the soil. Trujillo and Tela, Honduras, Central America (*Reinking* R 49).

Fusarium bulbigenum produces a wilt and rot of bulbs of *Narcissus*.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 4 to 14 days old are characterized by a fine cottony and fluffy mycelium that is white, cartridge buff, and at the base of the slant pale ochraceous salmon. A scant pionnotes of the latter color may be present. Cultures from 44 to 63 days old have a cottony and matted, cartridge buff, cream buff, and pale ochraceous buff mycelium. A warm buff pionnotes may be produced. Large wartlike heaps of amber yellow and warm buff sclerotia are frequently formed. On potato-agar plate 2 months old is produced a medium scant, pale pinkish buff mycelium.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have no aerial mycelium, but that in the substratum is dark vinaceous.

Oat agar.—Cultures 1 month old have a dense, matted, fine mycelium that is white, pale cinnamon pink with nigrosin violet at the sides of the growth. A warm buff pionnotes may be present.

Rice.—Cultures 21 days old are characterized by a medium dense and matted, white, cameo pink, thulite pink, rosolane purple, and Indian lake mycelium. Small whitish wartlike sclerotia may be present. Older cultures, from 1 to 2 months old, have a medium dense, fluffy and matted, cameo pink, thulite pink, and pomegranate purple mycelium. It may be leathery in places and yellow ocher. Sclerotia are present and a light pinkish cinnamon pionnotes may be produced. A slight benzoic odor is noted.

Potato-tuber plug.—Cultures 23 days old have a dense, cottony, white and seashell pink mycelium. Warm buff, wartlike sclerotia are present. Cultures 1 month to 80 days old have a dense cottony, in places leathery, white and light violet mycelium. On the glass the mycelium may be yellow ocher.

Melilotus stem.—Cultures 1 month old have a scant, pale pinkish buff mycelium.

Alnus stem.—Cultures 1 month old have a medium scant, pinkish cinnamon and cinnamon mycelium.

Mature corn stalk.—Cultures from 30 to 50 days old have a scant, in places powdery and in tufts, white, light buff, and cream color mycelium. It also may be mustard yellow in places.

Banana peel.—Cultures 26 days old have a scant, white and honey yellow mycelium. Three-month-old cultures are characterized by a scant, matted, sayal brown mycelium. Small white sclerotia may be produced.

Green bean pod.—Cultures 1 month old have a dense, white mycelium, typically with cream buff sclerotia. Older cultures, 1 to 2 months old, have a thin, sometimes velvety, matted, cartridge buff, pale pinkish buff, and cinnamon buff mycelium. Under certain conditions self digestion of the mycelium may take place. The slimy mass is then a deep olive buff.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 1 month old; conidia from mycelium:

Conidia—

- 0-septate, 57 per cent, 9 by 2.75 (5 to 15 by 2.25 to 3.5) μ .
- 1-septate, 22 per cent, 14 by 3.5 (9 to 18 by 3.25 to 4) μ .
- 2-septate, 3 per cent, 23 by 3.5 (19 to 29 by 3.25 to 4) μ .
- 3-septate, 13 per cent, 38 by 3.75 (29 to 45 by 3.5 to 4) μ .
- 4-septate, 2 per cent, 40 by 3.75 (35 to 47 by 3.5 to 4) μ .
- 5-septate, 2 per cent, 63 by 3.5 (41 to 46 by 3.5) μ .
- 6-septate, 1 per cent, 49 by 3.5 μ .

Oat agar; culture 16 days old; conidia from mycelium and pionsnotes:

Conidia—

- 0-septate, 3 per cent.
- 1-septate, 1 per cent.
- 2-septate.
- 3-septate, 82 per cent, 35 by 3.25 (26 to 45 by 2.75 to 3.5) μ .
- 4-septate, 12 per cent, 43 by 3.25 (33 to 52 by 2.75 to 3.5) μ .
- 5-septate, 2 per cent, 49 by 3.25 (42 to 56 by 2.75 to 3.75) μ .

Green bean pod; culture 14 days old; conidia from mycelium:

Conidia—

- 0-septate, 61 per cent, 10 by 3.5 (6 to 13 by 2.75 to 4) μ .
- 1-septate, 14 per cent, 21 by 2.75 (20 to 23 by 2.75 to 3.25) μ .
- 2-septate, 4 per cent, 23 by 3.75 (18 to 27 by 3.5 to 4) μ .
- 3-septate, 21 per cent, 31 by 3.5 (29 to 33 by 3.25 to 3.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

- 0-septate, 40 per cent, 9 by 3 (5 to 15 by 2.25 to 4) μ .
- 1-septate, 10 per cent, 17 by 3.25 (9 to 23 by 2.75 to 4) μ .
- 2-septate, 2 per cent, 23 by 3.5 (18 to 29 by 3.25 to 4) μ .
- 3-septate, 40 per cent, 36 by 3.5 (26 to 45 by 2.75 to 4) μ .
- 4-septate, 6 per cent, 41 by 3.5 (33 to 52 by 2.75 to 4) μ .
- 5-septate, 2 per cent, 46 by 3.25 (41 to 56 by 2.75 to 3.75) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Hard potato agar; culture 112 days old:

Chlamydospores (both conidial and mycelial)—

0-septate, conidial chlamydospores, 96 per cent, 6.5 by 5.5 (5.5 to 8 by 5 to 6.25) μ .

1-septate, conidial chlamydospores, 4 per cent, 10.5 by 4.75 (10 to 11 by 4.5 to 5) μ .

0-septate, mycelial chlamydospores, 82 per cent, 9 by 9 μ .

1-septate, mycelial chlamydospores, 8 per cent, 13.5 by 7 μ .

3. Subsection OXYSPORUM Wollenweber

Oxysporum WOLLENWEBER, Ann. Myc. 15 (1917) 2; Ber. der Deutsch. Bot. Gesell. 35 (1918) 741.

Sporodochia typically present, stroma more or less verrucose erumpent, sclerotia present, microconidia common. Macroconidia eight to ten times as long as thick.

Series CYANOSTROMA Wollenweber

Cyanostroma WOLLENWEBER, Ann. Myc. 15 (1917) 2; Ber. der Deutsch. Bot. Gesell. 35 (1918) 742.

Stroma more or less erumpent, tinged with blue.

FUSARIUM OXYSPORUM Schlechtendal emend. Wollenweber. Plate 2, fig. 4; text. fig. 29.

Fusarium oxysporum SCHLECHTENDAL, Fl. Berol. 2 (1824) 139; SMITH and SWINGLE, U. S. Bur. Plant Ind. Bull. 55 (1904); WOLLENWEBER, Phytopath. 3 (1913) 28; Journ. Agr. Research 2 (1914) 268; CARPENTER, Journ. Agr. Research 5 (1915) 183-209; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 220; WOLLENWEBER, Jahresber. d. Ver. f. Angew. Bot. 14 (1916) 2, 121-128; Ann. Myc. 15 (1917) 24; Ber. der Deutsch. Bot. Gesell. 35 (1918) 742; BISBY, Minn. Agr. Exp. Sta. Bull. 181 (1919) 1-47.

Sclerotial plectenchymic stroma knotty rugulose, dark blue, erumpent; conidia somewhat Isabella color or dirty yellow, in sporodochia or pionnotes, sporodochia spread out, convex to confluent; conidia spindle- to sickle-shaped, pedicellate, end cell somewhat constricted, typically 3-septate, 30 by 4 (18 to 40 by 3.25 to 4.5) μ ; rarer (up to 30 per cent), 4- to 5-septate, 35 by 4 (32 to 42 by 3.5 to 4.75) μ ; microconidia formed free in aerial mycelium that is grayish white, or in numerous false heads, globose, single-celled, 5 to 12 by 2 to 3.5 μ , chlamydospores globose, sometimes verrucose, single-celled, rarer 1-septate, 7 to 10 μ in diameter. On rice culture the fungus produces a benzolic odor.

Habitat.—In soil. Tela, Honduras, Central America (*Reinking R 138*).

Fusarium oxysporum is the cause of potato wilt of plants in various parts of the world. It also produces a tuber rot and a jelly end-rot of tubers along with *F. radicicola*. Upon inoculation, rots are produced in orange, tomato, cucumber, and apple fruits.(3)

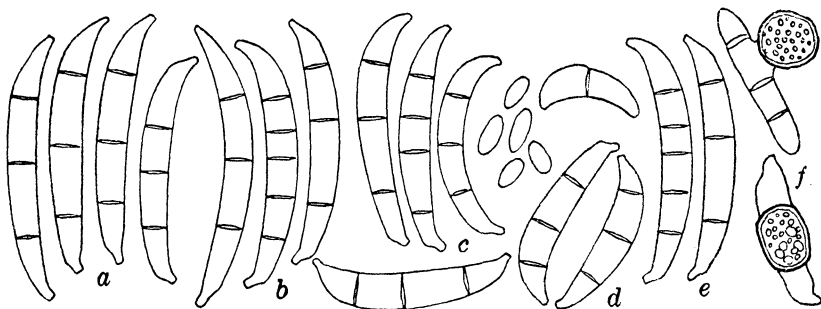


FIG. 29. *Fusarium oxysporum* Schlechtendal emend. Wollenweber; a, conidia from pionnotes of 2-month-old rice culture; b, conidia from pionnotes of 25-day-old hard potato-agar culture; c, conidia from pionnotes of 25-day-old hard potato-agar culture; d, conidia, short type, from sporodochia of 17-day-old *Melilotus*-stem culture; e, conidia from pionnotes of 23-day-old hard potato-agar culture; f, chlamydospores from 3-month-old green bean-pod culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a fluffy and dense, matted, white, cartridge buff, and ivory yellow mycelium. Terre-verte spots may be present at the base of the slant. A pinkish buff or pale ochraceous buff pionnotes is produced. Light buff and terre-verte sclerotia usually are developing. Cultures 45 to 90 days of age have a flattened and somewhat leathery, cartridge buff, cream buff, and shell pink mycelium. Dusky bluish green and deep delft blue wartlike sclerotia are usually present. Spots of dusky bluish green and bluish lavender may be present at the base as a sclerotial plectenchymic mass. A cream buff and pinkish buff sporodochial pionnotes may be present. On 2-month-old plates there are present a medium thin, pale pinkish buff mycelium and light ochraceous salmon sporodochia and pionnotes masses.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a medium scant, cottony, pale pinkish buff mycelium. Dusky dull bluish green sclerotia may be present here and

there over the plate. The mycelium in the substratum is burnt lake.

Oat agar.—Cultures 1 month old are characterized by a medium dense, somewhat matted, fine cottony, pale cinnamon pink and cameo pink mycelium. Spots of magenta red stroma may be present on the agar. Numerous large sclerotial masses 1 to 4 mm in diameter are usually present. When young they are light buff and when older dusky dull bluish green and deep delft blue. Salmon buff sporodochia and pionnotes masses are generally produced over the sclerotia and in places on the slant.

Rice.—Cultures 20 days old have a medium dense and matted, white, rose red, pomegranate purple, and rose color mycelium from the top to the bottom of the rice culture. An orange pink pionnotes may be present. The red color shows the acid modification. Cultures 2 to 3 months of age have a matted, spinel red, thulite pink, dark maroon-purple, madder violet, dark madder violet, and dull violet-black mycelium. The purple color shows the alkaline modification. Few dark maroon-purple sclerotia may be produced. Shrimp pink and salmon buff pionnotes masses are usually present. A strong benzolic odor is produced on rice.

Potato-tuber plug.—Cultures 22 days old have a scant, white and pale pinkish buff aerial mycelium, possibly with a spot or so of a dusky green-blue.⁽¹⁾ Wartlike heaps of sclerotia are usually present. When young they are warm buff and when older dusky green-blue⁽¹⁾ or deep delft blue. A pale ochraceous buff and light ochraceous salmon pionnotal mass is produced over the plug. Cultures 80 days old are similar except that a deep glaucous green and light porcelain green may be present on the sporodochia. The mycelium may also be pinkish buff and pale bluish lavender.

Melilotus stem.—Two-month-old growth is characterized by a medium scant, pale pinkish buff and pinkish buff mycelium over the stem. Small stromatic bodies of mycelium may be here and there. Light buff, warm buff, and dusky dull bluish green sclerotia in wartlike heaps, 1 to 3 mm in diameter, are present. They are usually covered with an ochraceous salmon pionnotes.

Alnus stem.—Cultures 1 month old have scant, pinkish buff mycelium on the twig with small, pale pinkish buff sporodochia here and there.

Mature corn stalk.—Cultures 54 days old have a fluffy and, in places, dense, white, seashell pink, terre-verte, and dusky dull violet^(1,2) mycelium. Vinaceous cinnamon or blue-violet-black minute sclerotia may be produced.

Banana peel.—Young cultures, 26 days old, have a medium scant, cottony, white mycelium with sclerotia in dusky bluish green wartlike heaps and few honey yellow sporodochia. Older cultures, up to 95 days old, have a scant, cartridge buff, pale ochraceous buff, and cinnamon buff mycelium. The sclerotia are light buff, warm buff, dusky olive green, dusky bluish green, deep delft blue, sayal brown, and blackish green-gray. Pinkish cinnamon, light ochraceous salmon, and light ochraceous buff sporodochia and pionnotes masses are present.

Banana fruit flesh.—Cultures 26 days old have a thin, matted, pale pinkish buff and light pinkish cinnamon mycelium.

Green bean pod.—Cultures 2 months old are characterized by a thin, matted, cartridge buff, cream buff, pale pinkish buff, pinkish buff, and cinnamon buff mycelium. Cinnamon buff and dusky bluish green sclerotia are produced. Few cinnamon buff and light ochraceous salmon sporodochia are present.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 14 days old; conidia from sporodochia:

Conidia—

0-septate, 3 per cent, 6 by 3.25 (4 to 8 by 2.25 to 4.5) μ .

1-septate, 4 per cent, 14 by 3.75 (12 to 18 by 3.5 to 4) μ .

2-septate, 2 per cent, 19 by 4.5 (18 to 22 by 4.5) μ .

3-septate, 69 per cent, 25 by 4.5 (20 to 29 by 3.75 to 4.5) μ .

4-septate, 18 per cent, 43 by 5 (43 to 44 by 5) μ .

5-septate, 4 per cent, 44 by 5 μ .

Hard potato agar; culture 25 days old; conidia from pionnotes:

Conidia—

3-septate, 68 per cent, 28 by 3.75 (23 to 32 by 3.5 to 4) μ .

4-septate, 30 per cent, 33 by 4 (30 to 36 by 4 to 4.52) μ .

5-septate, 2 per cent, 36 by 4 (32 to 39 by 4 to 4.25) μ .

Rice; culture 2 months old; conidia from pionnotes:

Conidia—

3-septate, 82 per cent, 34 by 4 (30 to 38 by 4 to 4.25) μ .

Melilotus; culture 17 days old; conidia from sporodochia:

Conidia—

3-septate, 26 by 4 (22 to 30 by 3.5 to 4.5) μ .

Alnus; culture 14 days old; conidia from sporodochia:

Conidia—

3-septate, 27 by 3.75 (23 to 31 by 3.25 to 4) μ .

Green bean pod; culture 21 days old; conidia from sporodochia:

Conidia—

1-septate, 18 per cent, 9 by 2.5 (5 to 12 by 2.25 to 3.5) μ .

1-septate, 12 per cent, 17 by 4.25 (14 to 19 by 4 to 4.5) μ .

2-septate, 10 per cent, 18 by 4.25 (16 to 20 by 4 to 4.5) μ .

3-septate, 52 per cent, 21 by 4.75 (18 to 24 by 4 to 5) μ .

4-septate, 5 per cent, 38 by 5 (37 to 39 by 5) μ .

5-septate, 3 per cent, 39 by 5 (35 to 41 by 5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

0-septate, 6 per cent, 8 by 2.75 (4 to 12 by 2.25 to 4.5) μ .

1-septate, 4 per cent, 15 by 4 (12 to 19 by 3.5 to 4.5) μ .

2-septate, 4 per cent, 18 by 4.25 (16 to 22 by 4 to 4.5) μ .

3-septate, 68 per cent, 29 by 4.25 (18 to 38 by 3.25 to 5) μ .

4-septate, 15 per cent, 38 by 4.75 (30 to 44 by 4 to 5) μ .

5-septate, 3 per cent, 41 by 4.75 (32 to 44 by 4 to 5) μ .

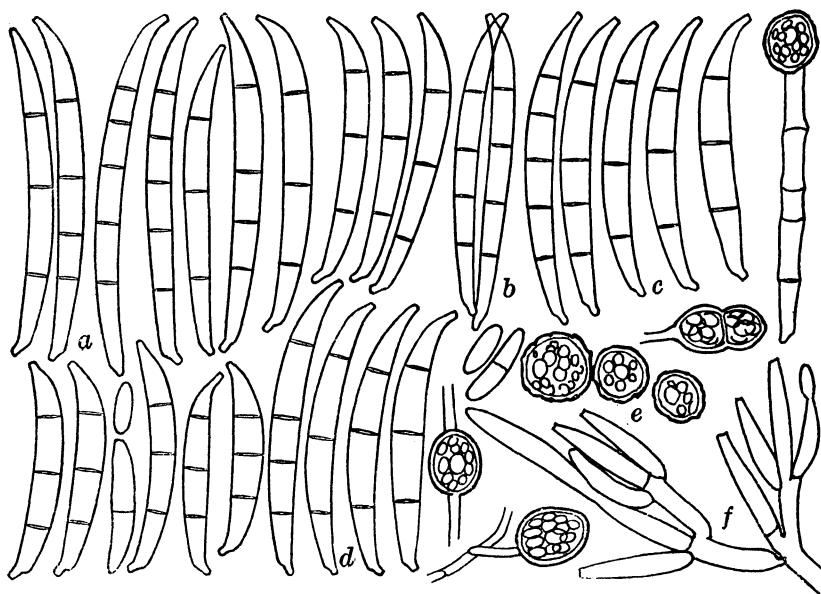


FIG. 30. *Fusarium oxysporum* Schlechtendal var. *nicotianae* Johnson; a, conidia, long and short types, from pionnotes of 28-day-old potato-agar culture; b, conidia from pionnotes of 22-day-old rice culture; c, conidia from pionnotes of 22-day-old *Melilotus*-stem culture; d, conidia from pionnotes of 22-day-old *Melilotus*-stem culture; e, chlamydospores from 22-day-old *Melilotus*-stem culture and 2-month-old hard potato-agar culture; f, conidiophore portion, from pionnotes of 3-month-old hard potato-agar culture.

FUSARIUM OXYSPORUM Schlechtendal var. NICOTIANAE Johnson. Plate 2, fig. 5; Plate 3, figs. 7 and 8; text fig. 30.

Fusarium oxysporum nicotianae JOHNSON, Journ. Agr. Research 20 (1921) 515-535; WOLLENWEBER, Angew. Bot. Zeit. für Erf. der Nutzpfl. 4 (1922) 9.

Johnson's diagnosis is as follows:

Mycelium pure white to light pinkish tinge, rather powdery due to presence of numerous microconidia; blue and light ochra-

ceous salmon color sclerotia found early on steamed potato; salmon color sporodochia and pionnotes present; conidia 3- to 5-septate, slightly larger than those of *F. oxysporum*; 3-septate, 35 by 4 (25 to 46 by 3.75 to 4.5) μ ; 5-septate, 44 by 4 (39 to 51 by 3.75 to 4) μ ; 6-septate, very rare; 0-septate, in sporodochia, rare, 7 by 2.5 μ ; 1-septate, equally rare, 10 by 2.75 μ ; 2-septate, 19 by 3.75 μ ; 0-septate, from mycelium, 8 by 3.5 (4 to 10 by 2.75 to 3.75) μ ; chlamydospores terminal, intercalary, mycelial and conidial, smooth, round, and frequently in masses, 8 (6 to 10) μ .

Differs from *F. oxysporum* by having longer conidia, up to 35 per cent 4- to 5-septate, 40 to 50 by 3.5 to 4.73 μ . Two types of spores are usually produced, long and narrow from pionnotes and sporodochia, short and wide from mycelium.

No benzolic odor is produced on rice by the strain described in the present discussion.

Habitat.—In soil. Tela and Trujillo, Honduras, Central America (*Reinking R 119*).

Fusarium oxysporum var. *nicotianae* is the cause of a tobacco wilt in the United States, but the pathogenicity of the soil fungus described here has not yet been proved. It is prevalent in the soil of banana plantations, having been found in 7 per cent of the total soil isolations.⁹

⁹ Experience has shown that such characters as slenderness, curvature, and size of normal conidia can only be relied upon under uniform conditions in so-called "high culture." Slight differences in these characters may, however, occur in growing the same fungus in single-spore cultures, both from one source and from different hosts or locations. Under such circumstances the fungus described here, as isolated from Honduras soil and identified as *F. oxysporum* var. *nicotianae*, may touch the border line or may be even a widespread saprophytic soil form of the banana wilt *Fusarium*, *F. cubense*. This saprophytic soil strain may have adapted itself to plants of economic importance, as *Musa* or other plants, gradually assuming parasitic habits. If this were so, *F. cubense* would include saprophytic and parasitic strains with or without odor, taxonomically speaking, at least the following four forms:

Forma 1: Saprophytic form producing a benzolic odor.

Forma 2: Saprophytic form without odor.

Forma 3: Parasitic form with odor, cause of banana wilt.

Forma 4: Parasitic form without odor.

Synonym *Fusarium cubense* var. *inodoratum* Brandes.

This viewpoint touches a weak point in *Fusarium* taxonomy, as it reveals the difficulties encountered in separating border-line varieties from related species in the section *Elegans*. It is, therefore, only to be regarded as a working hypothesis, which possibly would lead to a considerable simplification of the system.

GROWTH ON VARIOUS MEDIA

The growth characters on various media are similar to those discussed under *Fusarium oxysporum*. No benzolic odor is produced on rice by *Fusarium oxysporum* var. *nicotianae*.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 18 days old; conidia from mycelium and pionnotes:

Conidia—

- 0-septate, 33 per cent, 11 by 3.5 (5 to 14 by 2.25 to 3.5) μ .
- 1-septate, 17 per cent, 20 by 3.75 (14 to 23 by 3.5 to 4) μ .
- 2-septate, 4 per cent, 25 by 3.5 (17 to 27 by 3.5) μ .
- 3-septate, 45 per cent, 39 by 4 (21 to 46 by 3.5 to 5) μ .
- 4-septate, 1 per cent, 58 by 4.25 (41 to 59 by 3.5 to 5) μ .

Hard potato agar; culture 26 days old; conidia from mycelium and pionnotes:

Conidia—

- 0-septate, 1 per cent, 10 by 3.5 μ .
- 1-septate, 11 per cent, 15 by 3.5 (14 to 18 by 3.25 to 4) μ .
- 2-septate, 4 per cent, 22 by 3.5 μ .
- 3-septate, 40 per cent, 34 by 4 (29 to 41 by 3.5 to 4.5) μ .
- 4-septate, 7 per cent, 34 by 3.75 (33 to 34 by 3.5 to 4) μ .
- 5-septate, 28 per cent, 51 by 4.25 (45 to 56 by 3.5 to 5) μ .
- 6-septate, 2 per cent, 55 by 5 (41 to 55 by 4.5 to 5.5) μ .
- 7-septate, 4 per cent, 56 by 5 (50 to 59 by 4.5 to 5.5) μ .
- 8-septate, 3 per cent, 60 by 5.5 (58 to 64 by 5.5) μ .
- 9-septate.
- 10-septate, rare, 72 by 5.5 μ .

Hard potato agar; culture 39 days old; conidia from sporodochia and pionnotes:

Conidia—

- 0-septate, 34 per cent, 7 by 2.75 (5 to 11 by 2.25 to 3.5) μ .
- 1-septate, 3 per cent, 14 by 3.5 (14 to 16 by 3.25 to 3.5) μ .
- 2-septate, 2 per cent, 19 by 3.5 μ .
- 3-septate, 52 per cent, 32 by 4 (28 to 38 by 4 to 4.25) μ .
- 4-septate, 5 per cent, 35 by 4 (34 to 35 by 4) μ .
- 5-septate, 4 per cent, 38 by 4 (32 to 44 by 4) μ .

Green bean pod; culture 16 days old; conidia from mycelium and pionnotes:

Conidia—

- 0-septate, 24 per cent, 9 by 3 (5 to 17 by 2 to 4.5) μ .
- 1-septate, 8 per cent, 17 by 3 (14 to 18 by 2.75 to 3.5) μ .
- 2-septate, 6 per cent, 24 by 3.5 (23 to 27 by 3 to 4) μ .
- 3-septate, 61 per cent, 33 by 4 (25 to 45 by 3.25 to 4.5) μ .
- 4-septate, 1 per cent, 40 by 4.5 μ .

Potato-tuber plug; culture 20 days old; conidia from pionnotes:

Conidia—

- 3-septate, 75 per cent, 36 by 3.5 (30 to 42 by 3 to 4) μ .
- 4-septate, 22 per cent, 49 by 3.25 (46 to 51 by 3.25 to 3.5) μ .
- 5-septate, 3 per cent, 50 by 3.25 μ .

Melilotus; culture 24 days old; conidia from sporodochia:

Conidia—

3-septate, 29 by 4 (24 to 35 by 3.5 to 4.5) μ (short conidia type).

3-septate, 38 by 3.5 (35 to 42 by 3 to 4) μ (long conidia type).

4- to 5-septate, 42 by 3.5 (42 by 3.5 to 3.75) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia—

0-septate, 18 per cent, 7 by 2.75 (5 to 17 by 2.25 to 4.5) μ .

1-septate, 8 per cent, 16 by 3.25 (14 to 23 by 2.75 to 4) μ .

2-septate, 3 per cent, 24 by 3.5 (17 to 27 by 3 to 4) μ .

3-septate, 55 per cent, 36 by 4 (21 to 46 by 3.25 to 5) μ .

4-septate, 7 per cent, 42 by 4.25 (33 to 59 by 3.5 to 5) μ .

5-septate, 7 per cent, 44 by 4 (32 to 56 by 3.25 to 5) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Hard potato agar; culture 100 days old:

Chlamydospores, both mycelial and conidial—

0-septate, conidial, 83 per cent, 5.5 to 12 by 4 to 7.25 μ .

1-septate, conidial, 17 per cent, 9 to 18 by 4.5 to 5.25 μ .

0-septate, mycelial, 94 per cent, 5 to 12 by 5 to 9 μ .

1-septate, mycelial, 6 per cent, 9 to 16 by 6 to 8 μ .

FUSARIUM CUBENSE Erwin F. Smith. Plate 2, figs. 6 and 7; Plate 3, figs. 1 to 6; Plate 4, figs. 1 and 5; text fig. 31.

Fusarium cubense SMITH, Science N. S. 36 (1910) 754, 755; BRANDES, Phytopath. 9 (1919) 339-389; WOLLENWEBER, Angew. Bot. Zeit. für Erforsch. der Nutzpfl. 4 (1922) 7-11; Fus. Aut. Del. suppl. (1924) figs. 623-624.

Microconidia gradually attenuate toward the apex, end cell constricted, sickle-shaped, pedicellate, broader in the middle and generally more distinctly curved toward the apex, 3- (4 or 5-) septate, typically 3-septate, 35 by 4 (17 to 51 by 3 to 4.5) μ ; also 2- to 5-septate, 2- and 4-septate being commoner, 5-septate rare; 4-septate, 32 to 53 by 3.5 to 5.4 μ ; 5-septate, 40 to 57 by 3.5 to 3.75 μ ; sporodochia and pionnotes present; microconidia ovoid or elongate, 0- or 1-septate, mostly 0-septate, 5 to 17 by 2.25 to 4.5 μ ; 1-septate, 13 to 26 by 3.25 to 4 μ ; 2-septate, 18 to 28 by 3.5 to 4.5 μ ; frequently produced in abundance with absence of macroconidia on young cultures; chlamydospores abundant in old cultures, in mycelium (intercalary and terminal), in conidia, 0- or 1-septate, 4 to 9 (12) μ in diameter, often catenulate, 0-septate, 4.5 to 9 by 4 to 6.25 μ ; 1-septate, 9 to 12 by 4.5 to 7.25 μ . Strong benzolic odor on rice.

As with *F. oxysporum* var. *nicotianae* (see footnote 9, page 192), two types of spores may be produced, long and narrow from pionnotes, and short and wide from mycelium and older sporodochia. The most general spore type is the short and wide. *Fusarium cubense* and the organism described here as *F. oxysporum* var. *nicotianae* are very closely related, and one might best be included as a form of the other. *Fusarium cubense* differs from *F. oxysporum* var. *nicotianae* in producing

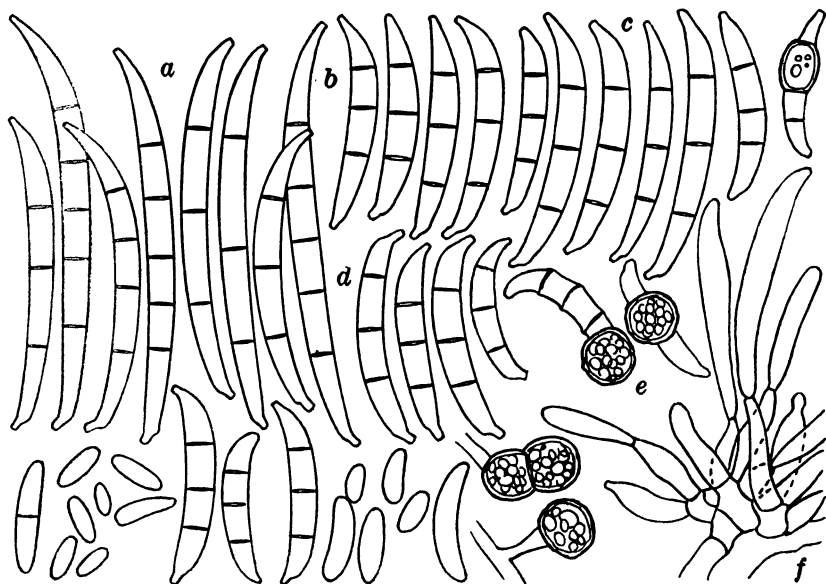


FIG. 31. *Fusarium cubense* Erwin F. Smith; a, conidia, long, rarer type, from pionnotes of 16-day-old hard potato-agar culture; b, conidia, typical, shorter type, from sporodochia of 14-day-old *Melilotus*-stem culture; c, conidia, typical, from pionnotes of 22-day-old *Melilotus*-stem culture; d, conidia, typical, from sporodochia of 2-month-old hard potato-agar culture; e, chlamydospores from conidia and mycelium of 22-day-old hard potato-agar culture; f, conidiophore, portion, from pionnotes of 19-day-old banana-peel culture.

a strong benzolic odor on rice, in the general lack of production of sporodochia and pionnotes, and in the production of smaller and fewer sclerotia on hard potato agar and media in general (Plate 3, figs. 2, 7, and 8). The form designated as *F. oxysporum* var. *nicotianae*, according to present investigations, (7) is not parasitic on the banana (*Musa sapientium* Linnæus). The similarity of the organisms from a morphological standpoint indicates that there may be wild saprophytic soil forms of known pathogenic species. Because of the close relationship established for these two strains it is evident that inoculation experiments are necessary to permit accurate differentiation of the

wilt-producing organisms. It would be interesting to determine whether or not the organisms here designated as *F. oxysporum* var. *nicotianae* and the other wilt-producing forms will actually produce disease in their respective hosts.

Habitat.—Vascular parasite causing wilt of banana (*Musa sapientium* Linnæus).^(4, 7) The organism also develops on the outer cut surfaces of diseased banana plants, in sporodochia on the surface of diseased banana leaves, occasionally on banana débris, and in the soil of diseased plantations. Tela and Trujillo, Honduras, Central America (*Reinking R 3 and 15*).

Fusarium cubense is prevalent in the soil of diseased banana plantations. Twelve per cent of the soil isolations in diseased banana plantations contained this species.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—The aërial mycelium at first is extremely fine, fluffy, cottony white, and from 2 to 4 mm in height. When 9 days old it is white or may be white and seashell pink at the base and top. Sometimes a patch of soft bluish violet is evident about the point of transfer. Sporodochia or a pionnotes may or may not be produced. Typically they are formed, and are salmon buff, light ochraceous salmon, pale pinkish buff, or pinkish buff. Sometimes concentric rings of sporodochia or pionnotes masses are formed about the point of transfer into the mycelium. Warm buff or cream color, but generally dusky green-blue,⁽²⁾ deep delft blue, dark delft blue, or cadet gray sclerotia or sclerotial plectenchymata may be developed at this age or somewhat earlier. They are at first formed at the base of the slant on the sides as small bodies in a row. The culture, up to the twenty-fifth day, usually retains its white or seashell pink with the addition of a pale ochraceous salmon or chamois ring at the top and base. The mycelial mass at this age generally becomes more or less matted. At 40 days old it is frequently cartridge buff and ivory yellow or cream buff and is matted and leathery toward the bottom of the slant. Niagara green or terre-verte stromatic folds may develop at the base. When sporodochia or a pionnotes have not developed well, a salmon buff or pinkish buff film may form over the agar slant, especially at the base adjoining the glass. As the culture becomes older the mycelium remains cartridge buff, usually with light buff, pale ochraceous buff, or pale pinkish buff above and below at the edges on the glass. Soft bluish violet may be

present on the agar about the point of transfer. At the age of 90 days and older the mycelial mass usually is flattened, sometimes papery, with the characteristic coloration described above. Over the slant on old typical cultures may be present the light ochraceous salmon, pale ochraceous buff, warm buff, or pinkish buff sporodochial and pionnotal masses. Generally on ordinary cultures, only the mycelial mass without spore bodies is present. In small wartlike heaps, more prevalent toward the base and edge of growth, are the dusky bluish green, dusky green-blue,⁽²⁾ but generally deep delft blue or dark delft blue sclerotia. On potato-agar plates 12 days old is produced a fine fluffy, medium dense, downy, aërial mycelium that is white with an indication of pale pinkish buff. A light ochraceous salmon pionnotes may be present; when developed the mycelial growth may be zonate.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old are characterized by fine, dense, cottony, pale cinnamon pink, seashell pink, salmon color mycelium. Flesh ocher may be present in places. Bluish slate black sclerotia or stromatic bodies, 0.5 to 1 mm in diameter, may be present here and there. The mycelium in the substratum is seashell pink, salmon buff, or bluish slate black.

Oat agar.—Cultures 1 month old have a fine, dense, cottony white, pale cinnamon pink, and salmon buff mycelium, possibly with spots of bluish slate black and petunia violet at the base of the slant. An Indian lake stroma usually is produced over the agar. Light buff, dusky dull bluish green, and bluish slate black sclerotia, 1 mm in diameter, are developed at the base. Sporodochia and pionnotes masses may or may not be present.

Rice.—The aërial mycelium at first is fine, cottony white, but in two weeks becomes dense above and cameo pink. On the sides it varies from thulite pink, spinel pink, to spinel red. Sporodochia and pionnotes masses are usually produced. Wartlike to cauliflowerlike sclerotia, ranging from 0.5 to 1 mm in diameter, with a light buff interior covered with white, cameo pink, thulite pink, spinel pink, or spinel red mycelium, are developed. A strong benzolic odor is usually evident at this age. As the culture grows older, the colors become darker due to a change from an acid to an alkaline modification. The mycelium at 60 days old may be spinel red, rosolane purple, Schoenfeld's purple, and sometimes Indian lake. The top mycelium is matted, and that on the sides is leathery. The benzolic odor at this age may not be so pronounced.

Potato-tuber plug.—The aërial mycelium is at first extremely fine, fluffy, and cottony white. As the culture grows older the mycelial mass becomes very dense, matted, and at 3 weeks may show a seashell pink or salmon buff in places, especially where it touches the glass. At this age sclerotia, 0.5 to 1 mm in diameter, may have developed, being formed in small wartlike heaps, the young warm buff, the older dark terre-verte, dusky bluish green, or dark delft blue; when 80 days old, the mycelial mass usually has changed to cartridge buff and has become matted and thick leathery. Some cultures become light buff, cream color, warm buff, pale pinkish buff, or ivory yellow, and may have spots of yellow ocher in places, especially on the glass. Spots of seashell pink, pinkish buff, pale bluish lavender, dusky bluish green, or deep delft blue may appear in places; the base is frequently honey yellow and leathery. The sclerotia remain the same. Sporodochia and pionnotes masses may be developed.

Melilotus stem.—Cultures 12 days old are characterized by a fine, fluffy, downy, aërial mycelium that is white, seashell pink and, in places where it touches the glass, clay color or Dresden brown. A pinkish cinnamon pionnotes made up of a mass of small sporodochia may be present on the stem. Dusky green-blue⁽²⁾ or deep delft blue, small sclerotia are often produced.

Alnus stem.—One-month-old growth is scant and seashell pink or pale pinkish buff. Sporodochia may be produced over the twig. When young they are salmon buff, when older chestnut brown.

Mature corn stalk.—At first the aërial mycelium that is developed is white, very scant, but fine and cottony. In cultures 50 days old the mycelium is still scant, white in places, usually seashell pink with pale ochraceous buff, light buff, or cream color in places. The older cultures may be in places madder violet or seldom terre-verte, dusky dull violet,^(1, 2) or dark slate violet. Plectenchymic bodies of the same color may be present in places. Cinnamon buff sclerotia are rarely developed. Pale flesh color or cream buff sporodochia or pionnotes masses may be developed.

Banana peel.—In young cultures only a scant, fine, cottony white mycelium is produced. In older cultures, up to 100 days old, the mycelium is pale orange yellow, pale ochraceous buff, light ochraceous buff, pale pinkish buff, pinkish buff, cinnamon buff, cartridge buff, or cream buff, especially on top and where

it touches the glass. Very scant production of mycelium or none at all may be characteristic of the older cultures. Small sporodochia or a pionnotes frequently may develop by the twentieth day. They are light ochraceous salmon, ochraceous buff, light pinkish cinnamon, cinnamon, or honey yellow. In older cultures, up to 100 days old, they usually are pinkish cinnamon or cinnamon. At 20 days of age, a few small wartlike sclerotia may have developed in places over the banana peel. They vary from Saccardo's umber, dusky bluish green, deep delft blue, bister, tawny olive, dusky drab, grayish olive, pale olive gray, blackish green-gray, to gray (pale gull gray), or black.

Banana fruit flesh.—At first a medium growth of fine, cottony, white mycelium is produced. When older it is matted and a pale pinkish cinnamon on top. Wartlike bone brown sclerotia may be formed within three weeks. An orange vinaceous dense pionnotes growth may develop over the surface of older cultures.

Green bean pod.—Young cultures are characterized by an extremely fine, fluffy, and cottony white mycelium. It gradually changes to cartridge buff or cream color, often with a pale pinkish buff coloration above on top. At the age of 15 days sporodochia or a pionnotes may have developed. They are light ochraceous salmon, light ochraceous buff, light pinkish cinnamon, cinnamon, and pinkish buff. As the growth becomes older, up to 100 days of age, the mycelial mass usually is matted, sometimes flat and more or less papery, and is white or cartridge buff with the extremities seashell pink to pale pinkish buff with yellow ocher or clay color where it touches the glass. The sporodochia and pionnotes masses may have changed to cinnamon, mikado brown, or Verona brown. Warm buff, cinnamon buff, dark delft blue, blackish brown, (3) or grayish olive wartlike heaps of sclerotia, from 0.5 to 1 mm in diameter, may be present.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 40 days old; conidia from sporodochia (short conidia type):

Conidia—

- 0-septate, 13 per cent, 9 by 3 (6 to 10 by 2.25 to 3.5) μ .
- 1-septate, 9 per cent, 17 by 3.5 (14 to 20 by 3.25 to 4) μ .
- 2-septate, 3 per cent, 23 by 4 (20 to 28 by 3.5 to 4.5) μ .
- 3-septate, 74 per cent, 32 by 4 (23 to 44 by 3.5 to 4.5) μ .
- 4-septate, 1 per cent, 47 by 4.5 μ .

Green bean pod; culture 30 days old; conidia from sporodochia (short conidia type):

Conidia—

- 0-septate, 5 per cent, 12 by 3 (10 to 14 by 2.75 to 3.5) μ .
- 1-septate, 7 per cent, 20 by 3.5 (15 to 26 by 3.25 to 3.75) μ .
- 2-septate, 3 per cent, 20 by 4 μ .
- 3-septate, 83 per cent, 32 by 4 (27 to 36 by 3.5 to 4.5) μ .
- 4-septate, 2 per cent, 37 by 4 μ .

Banana peel; culture 50 days old; conidia from sporodochia (short conidia type):

Conidia—

- 0-septate, 20 per cent, 9 by 2.75 (8 to 10 by 2.75) μ .
- 1-septate, 6 per cent, 16 by 2.75 μ .
- 2-septate, 3 per cent, 20 by 3.5 μ .
- 3-septate, 71 per cent, 30 by 4.25 (24 to 35 by 4 to 4.5) μ .

Hard potato agar; culture 16 days old; conidia from pionnotes (long conidia type):

Conidia—

- 3-septate, 59 per cent, 43 by 3.5 (34 to 51 by 3 to 3.75) μ .
- 4-septate, 36 per cent, 45 by 3.5 (40 to 50 by 3.5 to 3.75) μ .
- 5-septate, 5 per cent, 48 by 3.5 (40 to 57 by 3.5 to 3.75) μ .

Melilotus stem; culture 15 days old; conidia from pionnotes and sporodochia:

Conidia—

- 3-septate, 98 per cent, 34 by 4.25 (27 to 41 by 3.5 to 4.5) μ .
- 4-septate, 2 per cent, 41 by 4.5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 0-septate, 19 per cent, 10 by 3 (5 to 17 by 2.25 to 4.5) μ .
- 1-septate, 6 per cent, 18 by 3.5 (13 to 26 by 3.25 to 4) μ .
- 2-septate, 2 per cent, 23 by 4 (18 to 28 by 3.5 to 4.5) μ .
- 3-septate, 67 per cent, 35 by 4 (17 to 51 by 3 to 4.5) μ .
- 4-septate, 5 per cent, 43 by 4 (32 to 53 by 3.5 to 4.5) μ .
- 5-septate, 1 per cent, 48 by 3.5 (40 to 57 by 3.5 to 3.75) μ .

MEASUREMENTS OF CHLAMYDOSPORES ON DIFFERENT MEDIA

Hard potato agar; culture 3 months old:

Chlamydospores—

- 0-septate, in conidia, 75 per cent, 7 by 6 (5 to 10 by 4.5 to 8) μ .
- 1-septate, in conidia, 25 per cent, 12 by 4.5 (10 to 18 by 4.5 to 5.5) μ .
- 0-septate, in mycelium, 100 per cent, 7.5 by 7.5 (5.5 to 9 by 5.5 to 9) μ .

Green bean pod; culture 77 days old:

Chlamydospores—

- 0-septate, in conidia, 100 per cent, 6.5 by 6.5 (4.5 to 9 by 4.5 to 8) μ .

Banana peel; culture 3 months old:

Chlamydospores—

0-septate, in conidia, 87 per cent, 7 by 5 (4.5 to 9 by 4 to 6.25) μ .

1-septate, in conidia, 13 per cent, 10 by 5 (9 to 12 by 4.5 to 7.25) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Chlamydospores:

0-septate, in conidia, 83 per cent, 7 by 6 (4.5 to 10 by 4 to 8) μ .

1-septate, in conidia, 18 per cent, 12 by 5 (9 to 18 by 4.5 to 7.25) μ .

0-septate in mycelium, 100 per cent, 7.5 by 7.5 (5.5 to 9 by 5.5 to 9) μ .

FUSARIUM AURANTIACUM (Link) Saccardo emend. Wollenweber. Text fig. 32.

Fusarium aurantiacum WOLLENWEBER, Jahresber. d. Ver. f. Angew. Bot. 14 (1916) 2, 127; Ann. Myc. 15 (1917) 24.

Conidia moderately sickle-shaped, pedicellate, end cell constricted, in masses, Isabella color or dirty orange, 3-septate, 35 by 4.25 (30 to 40 by 3.5 to 4.5) μ ; 4- or 5-septate, 36 per cent; 5-septate, 43 by 4.25 (40 to 45 by 4 to 4.5) μ ; ocher sporodochia; blue sclerotia in abundance; chlamydospores present; odor absent.

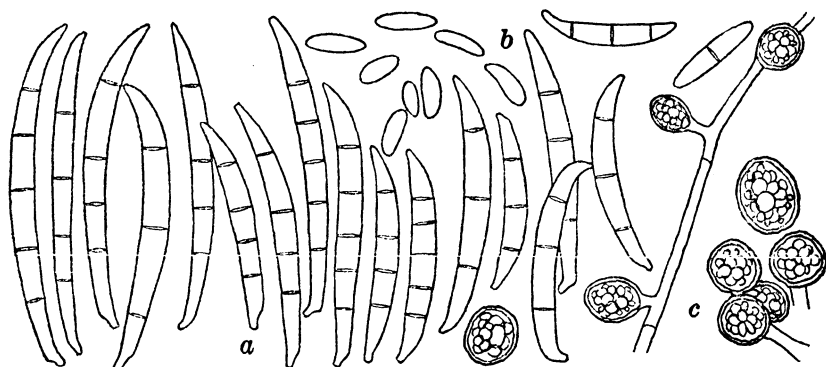


FIG. 32. *Fusarium aurantiacum* (Link) Saccardo emend. Wollenweber; a, conidia from sporodochia of 26-day-old potato-tuber plug culture; b, conidia from sporodochia and mycelium of 12-day-old hard potato-agar culture; c, chlamydospores from mycelium of 1-month-old hard potato-agar culture.

Differs from *F. oxysporum* var. *nicotianae* and *F. cubense* in having larger and broader spores and more abundant sclerotia.

Habitat.—In soil. Trujillo, Honduras, Central America (Reinking R 204). On roots of diseased sugar cane (*Saccharum officinarum* Linnæus). Jamaica (Hansford 7, R 227).

Fusarium aurantiacum produces a fruit rot of Cucurbitaceæ and a foot disease of cereals in Europe.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 2 months old are characterized by a medium dense, matted, cartridge buff mycelium. Light buff and chiefly dusky bluish green sclerotia in wartlike heaps, 1 to 2 mm in diameter, are present. Light ochraceous buff sporodochia may be produced over some of the sclerotia.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a medium dense, purplish vinaceous, aerial mycelium. Deep delft blue sclerotia are usually present. Pale cinnamon pink sporodochia may be found in with the mycelium. The mycelium in the substratum is warm blackish brown.

Oat agar.—Cultures 1 month old have a medium dense, matted, pale ochraceous salmon, with a little pinkish vinaceous mycelium over the slant. Large masses of wartlike heaps of sclerotia are produced. They are covered with a pale ochraceous salmon mycelium or are dusky dull bluish green or blackish brown,⁽³⁾ and measure from 1 to 4 mm in diameter. Large masses of ochraceous salmon sporodochia are produced. They may run together, producing a pionnotes.

Rice.—Cultures 23 days old are characterized by a variety of colors, starting at the top and ranging down from thulite pink, spinel pink, and spinel red. Large wartlike masses of sclerotia are produced.

Potato-tuber plug.—Growth 23 days old is similar to that described on oat agar, except for fewer sporodochia.

Melilotus stem.—Cultures 2 months old have a scant, cinnamon buff mycelium that is matted on top and thin over the sides of the stem. Large masses of deep delft blue sclerotia, measuring 0.5 to 3 mm in diameter, are produced all over the stem. Heaped, vinaceous cinnamon and pinkish cinnamon sporodochia that run together and form a pionnotes are also present in places on the sides of the stem.

Green bean pod.—Cultures 80 days old have a medium, thin matted, cartridge buff and cream buff mycelium. Small cinnamon buff sclerotia and Verona brown sporodochia are produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 27 days old; conidia from sporodochia:

Conidia—

0-septate, 12 per cent, 6 by 2.25 (4 to 8 by 1.5 to 2.75) μ .

1-septate, 4 per cent, 10 by 2.75 (9 to 11 by 2.75) μ .

2-septate, 2 per cent, 27 by 4 μ .

3-septate, 73 per cent, 33 by 4.25 (26 to 38 by 3.5 to 4.5) μ .

4-septate, 9 per cent, 36 by 4.25 (33 to 39 by 3.5 to 4.5) μ .

Hard potato agar; culture 66 days old; conidia from sporodochia:

Conidia—

0-septate, 4 per cent, 5 by 2.75 μ .

1-septate.

2-septate.

3-septate, 88 per cent, 34 by 4.5 (31 to 40 by 4 to 5) μ .

4-septate, 5 per cent, 34 by 4.75 (32 to 35 by 4.5 to 5) μ .

5-septate, 3 per cent, 47 by 4.25 (36 to 59 by 4 to 4.5) μ .

Green bean pod; culture 11 days old; conidia from sporodochia:

Conidia—

0-septate, 5 per cent, 6 by 3 (5 to 7 by 2.75 to 3.25) μ .

1-septate, 2 per cent, 14 by 2.75 μ .

2-septate, 2 per cent, 19 by 3.5 μ .

3-septate, 85 per cent, 31 by 4.25 (23 to 36 by 3.5 to 4.5) μ .

4-septate, 6 per cent, 36 by 4.5 (33 to 39 by 4.5) μ .

Potato-tuber plug; culture 26 days old; conidia from sporodochia:

Conidia—

3-septate, 73 per cent, 35 by 3.5 (27 to 44 by 3 to 4) μ .

4-septate, 24 per cent, 41 by 3.5 (33 to 50 by 3 to 4) μ .

5-septate, 3 per cent, 47 by 3.75 (42 to 52 by 3.5 to 4) μ .

Melilotus stem; culture 1 month old; conidia from sporodochia:

Conidia—

3-septate, 88 per cent, 35 by 3.5 (27 to 42 by 3 to 4) μ .

4-septate, 12 per cent, 47 by 4 (47 to 48 by 4) μ .

Oat agar; culture 21 days old; conidia from sporodochia:

Conidia—

3-septate, 60 per cent.

4-septate, 30 per cent.

5-septate, 10 per cent.

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 77 per cent, 34 by 4 (23 to 44 by 3 to 5) μ .

4-septate, 15 per cent, 41 by 4.25 (26 to 50 by 3 to 5) μ .

5-septate, 3 per cent, 47 by 4 (36 to 59 by 3.5 to 4.5) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Green bean pod; culture 16 days old:

Chlamydospores—

0-septate, mycelium, 80 per cent (6.25 to 7 by 6.25 to 10) μ .

1-septate, mycelium, 20 per cent (7 to 8 by 11 to 14) μ .

FUSARIUM LUTULATUM Sherbakoff. Text fig. 33.

Fusarium lutulatum SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta.

Memoir No. 6 (1915) 209-213; WOLLENWEBER, Ann. Myc. 15 (1917)

24.

Sherbakoff's description of *F. lutulatum* is as follows:

Macroconidia gradually attenuate toward the apex, usually distinctly pedicellate and uniformly curved throughout, without stronger curvature near apex, typically 3-septate, 34 by 4 (28

to 38 by 3.7 to 4.5 μ , also 2- to 5-septate; from small to medium sporodochia (up to 2 mm in diameter), often converging into pseudopionnotes, aërial mycelium, when present, short (mostly from 1 to 2 mm high), white, often, especially on agars in plate cultures, absent; color of conidia from nearly white (on aërial mycelium in the form of coarse powder) to dark vinaceous purple; sometimes on potato-stem plug, from one to a few large sporodochia (2 mm in diameter) of a bright orange color produced; substratum from colorless to that of the conidial mass; small bluish black sclerotia (0.5 mm in diameter) sometimes produced, and then in great numbers all over the substratum (on potato-tuber plug); zonation of colony very faint or none on neutral agars in plate cultures.

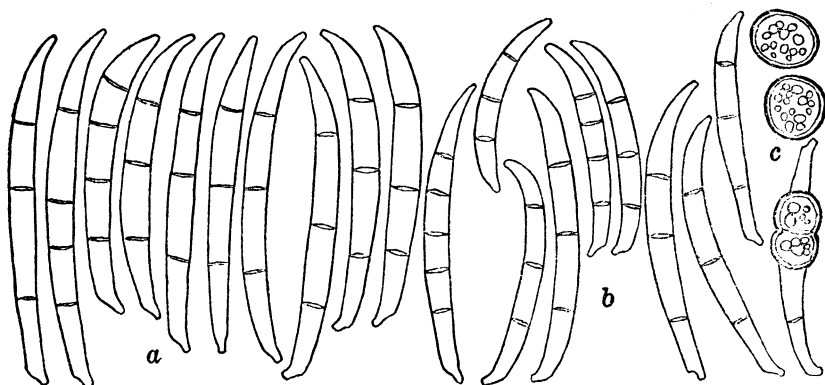


FIG. 38. *Fusarium lutulatum* Sherbakoff; a, conidia from pionnotes of 5-day-old hard potato-agar culture; b, conidia from pionnotes of 8-month-old hard potato-agar culture; c, chlamydospores from 8-month-old hard potato-agar culture.

To the diagnosis should be added that *F. lutulatum* has a strong benzolic odor on rice.

Habitat.—In vascular bundles of pseudostem of wilt-diseased banana plant (*Musa sapientium* Linnæus). Tela, Honduras, Central America (Reinking R 22).

Fusarium lutulatum Sherbakoff was placed as a synonym under *F. hyperoxysporum* Wollenweber in *Fusaria autographice delineata*, fig. 380, because of the presence of blue sclerotia and a perfect pionnotes, by which they differ from *F. oxysporum*. However, *F. hyperoxysporum* has a felty, luxuriant mycelial growth covering a thick plectenchymatic sheet (stroma) that is dark violet on potato agar. Large blue sclerotial bodies in

groups are common. The aërial mycelium of *F. lutulatum*, when present, is short (1 to 2 mm high) and often, especially on agars in plate cultures, it is absent. A violet color of the stroma also is produced on potato agar. Sometimes small blue sclerotial bodies are produced in large numbers. *Fusarium lutulatum* has in general more resemblance to the series *Pallens* of the subsection *Oxysporum* of *Elegans*, while *F. hyperoxysporum* is more related to *F. oxysporum* and belongs to the series *Cyanostroma* of the subsection *Oxysporum* of *Elegans*. Therefore, it seems better to separate both species and retain *F. lutulatum* as a legitimate species.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 21 days old are characterized by scant white aërial mycelium to none. A cinnamon buff pionnotes is produced all over the slant.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have no aërial mycelium, but have a Congo pink pionnotes mass over the plate.

Oat agar.—Cultures 21 days old have no aërial mycelium. A light vinaceous cinnamon and vinaceous cinnamon pionnotal growth is present over the slants. Cultures 1 month old may have minute, blackish brown⁽¹⁾ sclerotia at the base.

Rice.—Cultures 21 days old are characterized by the absence of aërial mycelium and the presence of a salmon color pionnotes over the rice. A strong benzolic odor is produced.

Potato-tuber plug.—Cultures 21 days old have a medium scant, matted, pale ochraceous salmon and light ochraceous salmon mycelium over the potato plug. A light ochraceous salmon and ochraceous salmon pionnotes is present over the tuber.

Green bean pod.—Cultures 2 months old have a thin, medium scant, white, cartridge buff, seashell pink, and salmon buff mycelium. A light ochraceous salmon and Verona brown pionnotes is present on the mycelium in places. Minute dark delft blue sclerotia may be produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 24 days old; conidia from pionnotes:

Conidia—

3-septate, 93 per cent, 38 by 3.75 (34 to 42 by 3.25 to 4) μ .

4-septate, 4 per cent, 40 by 3.75 (35 to 48 by 3.75) μ .

5-septate, 3 per cent, 40 by 3.5 μ .

Hard potato agar; culture 1 month old; conidia from pionnotes:

Conidia—

- 0-septate, 6 per cent, 9 by 2.75 (6 to 11 by 2.75) μ .
- 1-septate, 4 per cent, 13 by 3.5 (13 to 14 by 3.25 to 3.75) μ .
- 2-septate, 1 per cent, 19 by 3.75 (18 to 21 by 3.5 to 4) μ .
- 3-septate, 86 per cent, 30 by 4 (20 to 42 by 3.5 to 4.5) μ .
- 4-septate, 3 per cent, 43 by 4.25 (38 to 49 by 4 to 4.5) μ .

Green bean pod; culture 20 days old; conidia from pionnotes:

Conidia—

- 0-septate, 9 per cent, 8 by 3.25 (5 to 19 by 2.75 to 4) μ .
- 1-septate, 3 per cent, 20 by 3.75 (14 to 26 by 2.75 to 4.5) μ .
- 2-septate, 2 per cent, 23 by 3.75 (20 to 26 by 3.5 to 4) μ .
- 3-septate, 85 per cent, 30 by 4.25 (12 to 35 by 3.5 to 4.5) μ .
- 4-septate.
- 5-septate, 1 per cent, 44 by 4.5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 88 per cent, 33 by 4 (22 to 42 by 3.25 to 4.5) μ .
- 4-septate, 2 per cent, 42 by 4 (35 to 49 by 3.75 to 4.5) μ .
- 5-septate, 1 per cent, 42 by 4 (40 to 44 by 3.5 to 4.5) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Green bean pod; culture 77 days old:

Chlamydospores—

- 0-septate, conidial, 100 per cent, 6.5 by 6.5 (4.5 to 7.25 by 4.5 to 9) μ .

XIV. Section MARTIELLA Wollenweber

Including section *Martiella* Wollenweber and *Pseudomartiella* Wollenweber

Martiella WOLLENWEBER, Phytopath. 3 (1913) 30; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 244; WOLLENWEBER, Ber. der Deutsch. Bot. Gesell. 35 (1918) 738; WOLLENWEBER, SHERBAKOFF, REINKING, JOHANN, and BAILEY, Journ. Agr. Research 30 (1925) 341.

Macroconidia dorsiventral, spindle- to sickle-shaped, apex more or less curved, or rounded, base more or less subpedicellate; microconidia oval to oblong, mostly 0-septate; sporodochia and pionnotes present, white, pale ocher or golden; stroma greenish to blue or almost black; chlamydospores terminal, intercalary, 1-celled, 2-celled, catenulate or in heaps. Imperfect stage of the ascomycete *Hypomyces*, section *Pseudomartiella*.

FUSARIUM SOLANI (Martius pro parte) Appel and Wollenweber var. MINUS Wollenweber. Text fig. 34.

Fusarium solani minus WOLLENWEBER, Ann. Myc. 15 (1917) 55.

Macroconidia 3-septate, 27 to 33 by 4.25 to 5 μ ; chlamydospores terminal, intercalary, singly, catenulate or in heaps, sometimes

rugulose, 7 to 8 μ in diameter. For other characters see *F. solani*.

Habitat.—On mature leaves of standing banana plant, on cut end of banana rhizome (*Musa sapientium* Linnæus), on rotted stem of living plant (*Impatiens sultani*), and in soil. Tela, Honduras, Central America (Reinking R 130). On roots of diseased sugar cane (*Saccharum officinarum* Linnæus) and in soil. Jamaica (Hansford 6 and 19, R 226 and 239).

The organism is rather common on decaying parts of banana that have fallen to the ground.

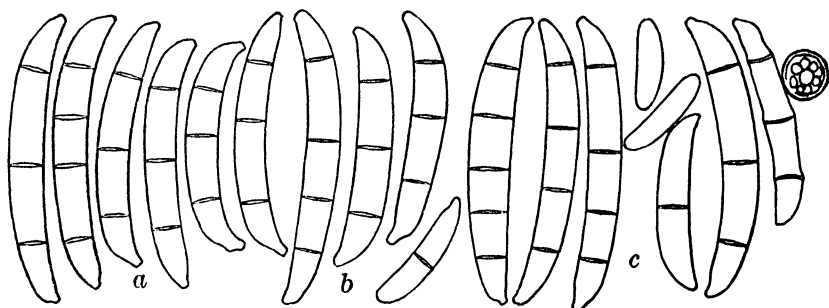


FIG. 34. *Fusarium solani* (Martius p. p.) Appel and Wollenweber var. *minus* Wollenweber; a, conidia from pionnotes of 25-day-old hard potato-agar culture; b, conidia from pionnotes of 15-day-old oatmeal-agar culture; c, conidia and chlamydospore from pionnotes of 16-day-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Growth on various media is similar to that discussed under *F. solani*.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 12 days old; conidia from sporodochia:

Conidia—

- 0-septate, 3 per cent, 8 by 3.25 (7 to 10 by 3.25) μ .
- 1-septate, 4 per cent, 18 by 4.75 (13 to 23 by 4.5 to 5) μ .
- 2-septate, 2 per cent, 27 by 4.5 (23 to 31 by 4.5) μ .
- 3-septate, 88 per cent, 33 by 5 (25 to 41 by 5) μ .
- 4-septate, 2 per cent, 37 by 5.25 (36 to 39 by 5.25) μ .
- 5-septate, 1 per cent, 39 by 5.5 μ .

Hard potato agar; culture 30 days old; conidia from sporodochia:

Conidia—

- 0-septate, 6 per cent, 13 by 4 (9 to 17 by 3.25 to 4.5) μ .
- 1-septate, 11 per cent, 19 by 4.5 (14 to 23 by 4 to 5) μ .
- 2-septate, 8 per cent, 23 by 4.75 (20 to 27 by 4.5 to 5) μ .
- 3-septate, 72 per cent, 32 by 4.75 (27 to 38 by 4.5 to 5) μ .
- 4-septate, 3 per cent, 39 by 5.5 (40 to 42 by 5 to 6) μ .

Green bean pod; culture 11 days old; conidia from sporodochia:

Conidia—

0-septate, 3 per cent, 11 by 3.25 μ .

1-septate, 3 per cent, 14 by 5 μ .

2-septate, 2 per cent, 23 by 4.5 μ .

3-septate, 81 per cent, 30 by 5.25 (26 to 34 by 5 to 5.5) μ .

4-septate, 11 per cent, 39 by 5.5 (35 to 40 by 5 to 6) μ .

Green bean pod; culture 30 days old; conidia from sporodochia:

Conidia—

0-septate, 6 per cent, 13 by 4 (10 to 17 by 3.5 to 5) μ .

1-septate, 8 per cent, 22 by 4.5 (19 to 25 by 4 to 5) μ .

2-septate, 9 per cent, 26 by 4.75 (21 to 28 by 4.5 to 5) μ .

3-septate, 75 per cent, 32 by 5 (27 to 37 by 5) μ .

4-septate, 2 per cent, 37 by 5.25 (36 to 37 by 5 to 5.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 79 per cent, 32 by 5 (25 to 41 by 4.5 to 5.5) μ .

4-septate, 5 per cent, 38 by 5.25 (35 to 42 by 5 to 6) μ .

5-septate, 1 per cent, 39 by 5.5 μ .

MEASUREMENTS OF CHLAMYDOSPORES

Hard potato agar; 12 days old:

Chlamydospores—

0-septate, mycelium, 100 per cent, 7.25 by 7.25 μ .

1-septate, mycelium.

FUSARIUM SOLANI (Martius pro parte) Appel and Wollenweber var. **SUFFUSCUM** Sherbakoff. Text fig. 35.

Fusarium solani suffusum SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 254-255; WOLLENWEBER, Ann. Myc. 15 (1917) 25.

Sherbakoff's description is as follows:

Differs from *F. solani* and *F. solani* var. *cyaneum* mainly by typically well-developed, uniform, fine, aërial mycelium, with a mass of chlamydospores at maturity which gives it a pale brownish tint; by sparse conidial production on aërial mycelium; and by the fact that sporodochia are usually few and distant from one another.

Habitat.—On diseased cacao pod (*Theobroma cacao* Linnæus). Panama, Central America (*Dunlap* 135, *R* 114). In the soil. Tela, Honduras, Central America (*Reinking* *R* 199).

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 14 days old are characterized by a medium scant, cottony, tufted, ivory white mycelium that may have a chamois ring at the sides and base of the slant. Cultures 1 to 3 months old have a medium dense and matted, cartridge buff, cream buff, and light buff mycelium. Frequently

no sporodochia are produced. When found in the older cultures they are chamois or cinnamon.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a scant aërial mycelium to none. The mycelium in the substratum is cinnamon buff.

Oat agar.—Cultures 1 month old have a dense, white, and cartridge buff mycelium with edges of wood brown. Generally no fruiting bodies are produced.

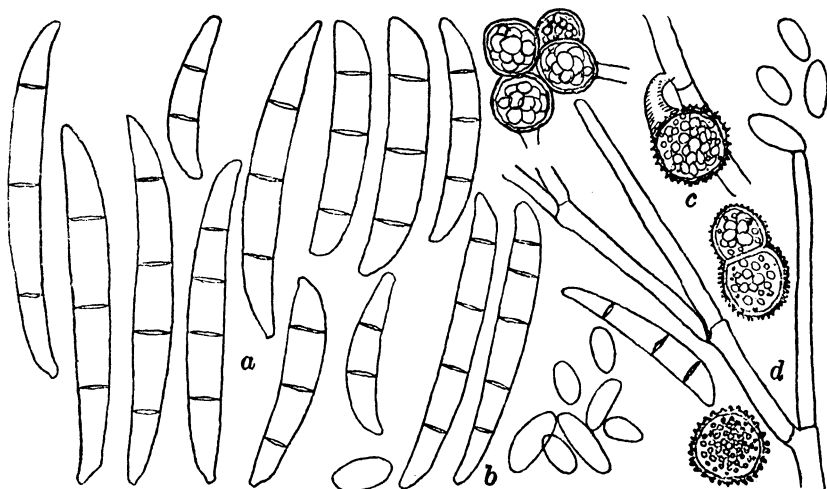


FIG. 35. *Fusarium solani* (Martius p. p.) Appel and Wollenweber var. *suffusum* Sherbakoff; a, conidia from mycelium of 2-month-old hard potato-agar culture; b, conidia from mycelium of 1-month-old *Melilotus*-stem culture; c, chlamydospores from 2-month-old hard potato-agar culture; d, conidiophore from mycelium of 1-month-old green bean-pod culture.

Rice.—Cultures 20 days old have a dense, matted, white and amber yellow mycelium. It may be leathery at the base where it touches the glass. Old cultures, 2 months of age, have a thin, matted, cartridge buff and chamois mycelium that may also be leathery in places.

Potato-tuber plug.—Cultures 25 days old are characterized by a dense, matted, white, light buff, and cream color mycelium. Cultures 2.5 months old have a thin, matted, and leathery mycelium that is cream color, pinkish buff, and cinnamon.

Melilotus stem.—Cultures 2 months old have a scant, white, aërial mycelium.

Alnus stem.—Cultures 1 month old are characterized by a scant, white and pale pinkish buff mycelium.

Green bean pod.—Cultures 45 days old have a thin, matted, cartridge buff, light buff, and warm buff mycelium.

Banana peel.—Cultures 25 days old have a medium scant, white and cinnamon brown mycelium.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 14 days old; conidia from small sporodochia:

Conidia—

0-septate, 3 per cent, 8 by 2.75 (7 to 10 by 2.75) μ .

1-septate, 36 per cent, 19 by 4 (16 to 23 by 3.5 to 4.5) μ .

2-septate, 28 per cent, 23 by 4.5 (23 to 24 by 4.5 to 5) μ .

3-septate, 33 per cent, 26 by 4.5 (23 to 28 by 4.5 to 5) μ .

Green bean pod; culture 31 days old; conidia from mycelium:

Conidia—

0-septate, 89 per cent, 7 by 3.75 (6 to 13 by 2.75 to 5) μ .

1-septate, 4 per cent, 12 by 3.75 (10 to 14 by 3.25 to 4.5) μ .

2-septate.

3-septate, 7 per cent, 29 by 4.75 (24 to 33 by 4.5 to 5) μ .

4-septate, rare, 32 by 5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 15 per cent, 28 by 4.5 (23 to 33 by 4.5 to 5) μ .

4-septate, rare, 32 by 5 μ .

MEASUREMENTS OF CHLAMYDOSPORES

Hard potato agar; culture 2 months old:

Chlamydospores—

0-septate, in mycelium, 6 to 10 by 6 to 10 μ .

1-septate, in mycelium, 11 to 15 by 6 to 7 μ .

FUSARIUM SOLANI (Martius pro parte) Appel and Wollenweber. Text. fig. 36.

Fusarium solani APPEL and WOLLENWEBER, Arb. K. Biol. Anst. Land-u. Forstw. 8 (1910) 65-78; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 251-253; CARPENTER, Journ. Agr. Research 5 (1915) 204; WOLLENWEBER, Ann. Myc. 15 (1917) 25.

Macroconidia scattered in mycelium or in false heads, in sporodochia or pionnotes, spindle-shaped or slightly curved, typically broader in upper half of length, rounded to slightly constricted apex, slightly pedicellate, or not at all, 1- to 5-septate, typically 3-septate, 30 to 40 by 5 to 6 (25 to 45 by 4.5 to 6.5) μ ; fewer 2- and 4-septate; 1-septate, 15 by 4 μ ; 5-septate, 42 to 48 by 6 μ ; conidia mass brownish white, in older cultures light brown and sometimes with green or greenish blue; plectenchymata sometimes greenish blue in older cultures, and white or brownish white in younger; chlamydospores terminal, intercalary, in mycelium and conidia, 1-celled, spherical or pear-shaped, 8.5 by 8 μ , 2-celled, 12 by 7.75 μ , less seldom in chains or heaps, smooth, sometimes definitely rugose.

Fusarium solani has a broad type of conidia.

Habitat.—In bark rot of Washington navel orange (*Citrus sinensis* Osbeck) and in the soil. Tela and Trujillo, Honduras, Central America (Reinking R 101).

Fusarium solani is generally regarded as a saprophyte, but under exceptional circumstances may become a weak wound parasite.

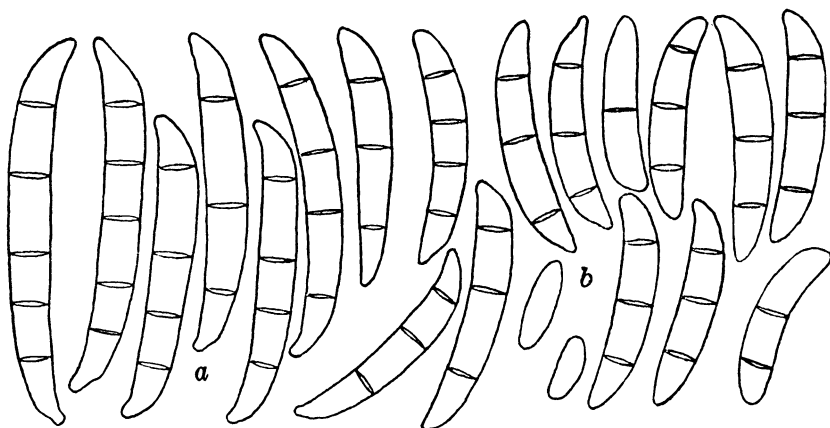


FIG. 36. *Fusarium solani* (Martius p. p.) Appel and Wollenweber; a, conidia from pionnotes of 24-day-old hard potato-agar culture; b, conidia from pionnotes of 3-month-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 1 month old are characterized by a loose, coarse, woolly, granular, white to cartridge buff mycelium. Pionnotes masses are produced abundantly in large heaps and are cream buff and olive buff when young, and when older are citrine drab, often with slight indication of French green. Older cultures, 3 months old, have a cartridge buff and deep olive buff mycelium and the pionnotes masses and sporodochia are frequently glaucous green or Montpellier green. One-month-old potato agar plates have a loose, coarse, woolly, granular, white to cartridge buff aerial mycelium over the plate. Few cream color tuberculate sporodochia are produced here and there. There is a slight indication of zonation. A plectenchymic mass that is porcelain green may be produced frequently in the center of the plate.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a white to cartridge buff aerial mycelium, and that in the substratum is cinnamon buff and clay color. A dusky dull bluish green pionnotes may be present in the center of the plate.

Oat agar.—Cultures 1 month old are characterized by a medium coarse to fine woolly mycelium that is white to cartridge buff. Sporodochia and pionnotes masses are produced in large groups over the slant. They are cartridge buff and olive buff.

Rice.—Cultures 1 month old have a scant mycelium that is light buff, buckthorn brown, Hessian brown, with yellow ocher in places. Pionnotes masses and sporodochia are produced. They are pinkish buff, seashell pink, and light russet, vinaceous, and occasionally with pale glaucous green. The rice is colored flesh pink, brick red, and dragon's blood red. On the addition of a 10 per cent potassium hydroxide solution, the reds change to dusky violet.

Potato-tuber plug.—Cultures 1 month old have a loose, coarse, woolly, granular mycelium that is white to cartridge buff, often with dark terre-verte at base. Large masses of sporodochia that run together, forming a pionnotes, are usually produced. They are mostly cartridge buff, pale olive buff, and glaucous. Some are deep lichen green and Niagara green. Small plectenchymic sclerotialike masses, 1 to 3 mm in diameter, may sometimes be produced. They are blackish brown.⁽³⁾

Melilotus stem.—One-month-old growth is characterized by a loose, coarse, woolly, granular, white to cartridge buff mycelium. Cream color pionnotes masses and sporodochia are present over the stem in small and large heaps. They may be glaucous green in places. Blackish brown⁽³⁾ small sclerotia may be produced.

Alnus stem.—Cultures 1 month old have a scant, white to cartridge buff aerial mycelium. Small, pale pinkish buff sporodochia are produced over the stem from the lenticels. They may be in columns, from 1 to 2 mm long.

Green bean pod.—Cultures 2 months old are characterized by having a medium thick, matted, cartridge buff and ivory buff mycelium. Large, spherical, pinkish buff, chamois, deep olive buff, citrine drab, deep olive, and deep bluish gray-green sporodochia are produced.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 35 days old; conidia from sporodochia:

Conidia—

- 0-septate, 3 per cent, 13 by 4.5 (11 to 14 by 3.25 to 5) μ .
- 1-septate, 6 per cent, 17 by 4.75 (13 to 19 by 4 to 5.5) μ .
- 2-septate, 6 per cent, 27 by 5.25 (22 to 30 by 5 to 5.5) μ .
- 3-septate, 68 per cent, 33 by 5.25 (24 to 51 by 5 to 5.25) μ .
- 4-septate, 16 per cent, 45 by 5.5 (41 to 49 by 5.25 to 6) μ .
- 5-septate, 1 per cent, 50 by 6.25 μ .

Green bean pod; culture 11 days old; conidia from sporodochia:

Conidia—

0-septate, 3 per cent, 11 by 4.5 (10 to 13 by 3.25 to 5.5) μ .

1-septate, 4 per cent, 19 by 4.75 (15 to 23 by 4 to 5.5) μ .

2-septate, 1 per cent, 24 by 5.5 (23 to 25 by 5 to 6) μ .

3-septate, 84 per cent, 36 by 5.25 (25 to 45 by 5 to 5.5) μ .

4-septate, 8 per cent, 41 by 5.5 (37 to 45 by 5.25 to 6) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 76 per cent, 35 by 5.5 (24 to 51 by 5 to 6.25) μ .

4-septate, 12 per cent, 43 by 5.5 (37 to 49 by 5.25 to 6) μ .

5-septate, 1 per cent, 50 by 6.25 μ .

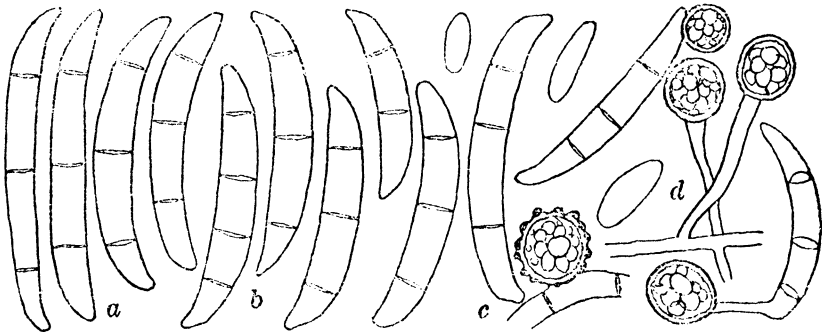


FIG. 37. *Fusarium alluviale* Wollenweber and Reinking; a, conidia from pionnotes of 25-day-old hard potato-agar culture; b, conidia from sporodochia of 21-day-old *Melilotus*-stem culture; c, conidium from pionnotes.

FUSARIUM ALLUVIALE Wollenweber and Reinking. Plate 2, fig. 8; text fig. 37.

Fusarium alluviale WOLLENWEBER and REINKING, *Phytopath.* 15 (March, 1925) 167.

Stroma erumpent, rugose, greenish blue; conidia dorsiventral, spindle- to sickle-shaped, top cell beak-shaped, basal cell slightly pedicellate, in sporodochia, in pionnotes or scattered, in masses from white to chestnut brown; 3-septate, 29 to 34 by 4.25 to 5.25 (25 to 44 by 4 to 6.25) μ ; seldom 4-septate, 32 to 43 by 4 to 6 μ ; in aërial mycelium smaller conidia also present, 0-septate, 9 to 14 by 3 to 4.5 μ , and 1-septate, 15 to 25 by 4 to 5.25 μ ; chlamydospores terminal, intercalary, sometimes spiny, in mycelium and in conidia, mostly unicellular, 6 to 11 μ in diameter. Strong odor produced on various culture media.

Habitat.—In alluvial soil. Trujillo, Honduras, Central America (Reinking R 188).

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a thin matted, powdery, cartridge buff and cinnamon buff my-

celium, sometimes with spots of lichen green or glaucous blue in places and buckthorn brown at the base. Cultures 1 month old have a matted, fine felty, white to cartridge buff mycelium that may be in zones at the base of the slant. Pionnotes masses are produced often in zones about the point of transfer, and they are cream buff. Older cultures, up to 3 months of age, show no change in the mycelium, but the heaped and scattered sporodochia are chamois, honey yellow, and deep olive. On one-month-old potato-agar plates a scant, usually distinctly zonate, cartridge buff aërial mycelium is produced. A cream buff and glaucous green pionnotes may be present.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a scant, white and pinkish buff, slightly zonate, aërial mycelium. The mycelium in the substratum is sayal brown.

Oat agar.—Cultures 1 month old are characterized by a medium dense, medium fine woolly, white and cartridge buff mycelium. Large wartlike heaps of sclerotia, 1 to 4 mm in diameter, are usually present. They may be covered with pionnotes or sporodochia. The interior of the sclerotia is buckthorn brown, while the exterior is bluish slate black. The sporodochia and pionnotes masses are deep olive buff. A characteristic, very strong odor is produced.

Rice.—Cultures 20 days old have a scant aërial mycelium that is citron yellow, light perilla purple, in places sorghum brown, and dusky greenish blue and petunia violet in places. Cream color or vinaceous buff sporodochia and pionnotes masses may be produced. Cultures 1 month old have a scant white aërial mycelium, usually with a characteristic black ring on the top of the rice. The mycelium on the glass may be burnt lake. The rice itself is colored brick red and dragon's blood red. Small, cartridge buff sporodochia are usually present. On addition of a 10 per cent solution of potassium hydroxide the liquid changes to dark vinaceous. Cultures 2 months old have a leathery mycelium and may have light buff or vivid purple wartlike sclerotia. The mycelium may have changed in places to perilla purple, dark vinaceous purple, or dark slate purple. The strong characteristic odor is produced.

Potato-tuber plug.—Cultures 20 days old have a felty, white, cream color, and in patches dark greenish olive mycelium. Few small ivory yellow sclerotia may be developed. Cream buff sporodochia and pionnotes masses are present. Growth 1 month old is short, fine cottony, matted, and thin felty in places. It is

white or buckthorn brown, deep lichen green, and rejane green in places. Small, bone brown sclerotia may be present.

Melilotus stem.—Cultures 1 month old are characterized by a medium scant, fine fluffy mycelium that is pale grayish vinaceous to russet vinaceous with drops of dark vinaceous brown water here and there. The liquid at the base of the tube turns dark vinaceous brown. Tilleul buff and pale olive buff sporodochia and pionnotes masses are produced on the mycelium that develops over the liquid and on the sides of the stem.

Alnus stem.—Cultures 1 month old have a scant white, aërial mycelium. Small, pale pinkish buff and pinkish buff sporodochia and pionnotes masses are developed here and there over the twig.

Green bean pod.—Cultures 1 to 2 months old have a medium thin, matted, cartridge buff, pinkish buff, and cinnamon buff mycelium over the bean. Masses of honey yellow and pinkish cinnamon sporodochia and pionnotes are usually present.

Banana peel.—Cultures 1 month old have a scant, cartridge buff mycelium with small pinkish buff and cinnamon buff sporodochia over the peel.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 10 days old; conidia from sporodochia:

Conidia—

0-septate, 34 per cent, 11 by 4 (9 to 13 by 3.25 to 5.25) μ .

1-septate, 28 per cent, 19 by 4.25 (15 to 28 by 3.5 to 5) μ .

2-septate, 4 per cent, 28 by 5 (27 to 30 by 5) μ .

3-septate, 33 per cent, 34 by 5.5 (25 to 39 by 5.25 to 6) μ .

4-septate, 1 per cent, 43 by 4 μ .

Oat agar; culture 2 weeks old; conidia from sporodochia:

Conidia—

3-septate, 75 per cent, 35 by 4.25 (30 to 40 by 4 to 5) μ .

4-septate, 24 per cent.

Green bean pod; culture 9 days old; conidia from sporodochia:

Conidia—

0-septate, 27 per cent, 12 by 3.75 (7 to 15 by 3.25 to 4.5) μ .

1-septate, 23 per cent, 20 by 4.75 (16 to 25 by 3.5 to 5) μ .

2-septate, 5 per cent, 25 by 5 (23 to 30 by 4.5 to 5.25) μ .

3-septate, 44 per cent, 44 by 5.25 (24 to 39 by 5 to 6) μ .

4-septate, 1 per cent, 38 by 5.75 (38 to 41 by 5.5 to 6) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

0-septate, 20 per cent, 11 by 3.75 (7 to 15 by 3.25 to 5.25) μ .

1-septate, 17 per cent, 19 by 4.5 (15 to 28 by 3.5 to 5) μ .

2-septate, 3 per cent, 26 by 5 (23 to 30 by 4.5 to 5.25) μ .

3-septate, 50 per cent, 38 by 5 (24 to 40 by 4 to 6) μ .

4-septate, 9 per cent, 40 by 5 (38 to 43 by 4 to 6) μ .

MEASUREMENTS OF CHLAMYDOSPORES ON DIFFERENT MEDIA

Chlamydospores:

0-septate, conidia, 6.5 to 8 by 6.5 to 8 μ .

0-septate, mycelium, 6 to 11 by 6 to 11 μ .

FUSARIUM MARTII Appel and Wollenweber var. **MINUS** Sherbakoff. Plate 4, figs. 2, 3, 4, and 6; text fig. 38.

Fusarium martii minus SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 249-250; WOLLENWEBER, Ann. Myc. 15 (1917) 26.

Sherbakoff's description is as follows:

Differs from *F. martii* and *F. martii* var. *viride* by having smaller, 3-septate conidia, 36.7 by 4.8 (30 to 44 by 4.55 to 5.1) μ , usually prominent development of plectenchymic, wartlike stromata, and fewer and larger sporodochia. Color of substratum, on potato agar, rich in glucose, from light gray to drab and dark olive buff, with a fuscous-colored spot at the point of inoculation.

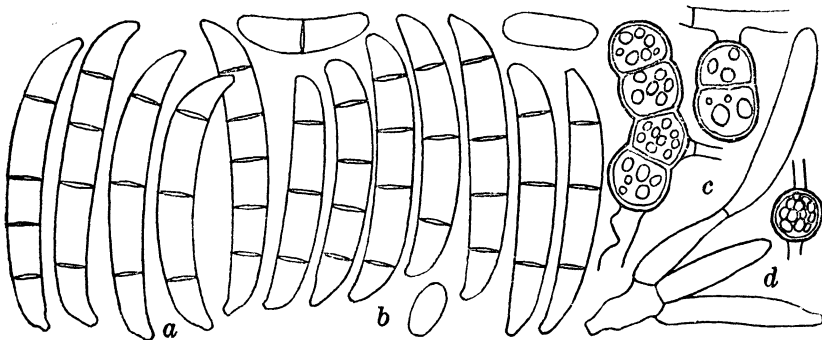


FIG. 38. *Fusarium martii* Appel and Wollenweber var. *minus* Sherbakoff; a, conidia from pionnotes of 22-day-old hard potato-agar culture; b, conidia from pionnotes of 3-month-old hard potato-agar culture; c, chlamydospores from 3-month-old hard potato-agar culture; d, conidiophore from sporodochia of 11-day-old green bean-pod culture.

Habitat.—On decaying banana bunch, on cut surfaces of pseudostem of banana, in interior of rhizome of banana (*Musa sapientium* Linnæus) after having been cut and allowed to stand for a day; in crown rot of citrus (*Citrus aurantifolia* Swingle) and in the air and soil. Tela and Trujillo, Honduras, Central America (*Reinking R 65*).

Fusarium martii var. *minus* is very common in the soil throughout banana plantations. Forty-four per cent of all soil isolations made, comprising three hundred sixty-five, were found to contain this variety. It is also rather common on decaying banana parts.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a medium dense, coarse, cottony, and in places tufted mycelium that is ivory yellow, cartridge buff, frequently with concentric rings of thick and thin mycelium or rings of terre-verte. Pinkish buff, cinnamon buff, and ochraceous buff sporodochia and heaped pionnotes masses are produced in places over slant, especially at the base. Cultures 1 month old have the same loose, medium coarse, woolly and granular, white to cartridge buff mycelium. The pionnotes may have changed to glaucous green, light terre-verte, bluish gray-green, or citrine drab. Older cultures, 3 months of age, have a scant, coarse, cottony white, cartridge buff, and cream buff mycelium with yellowish glaucous on the glass. The sporodochia and pionnotes masses are chamois, honey yellow, cream buff, mustard yellow, olive buff, pale glaucous green, and deep glaucous green. Frequently they are in concentric rings about the point of transfer. Mummy brown sclerotia may be present. On potato-agar plates 1 month old a loose, medium coarse, granular, woolly, white to cartridge buff mycelium is produced, a dusky green-blue(2) stroma may be present and the mycelium may be zonate, cream buff, chamois, deep olive buff, or sometimes glaucous green; pionnotes masses and sporodochia are present here and there on the plate.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a short, woolly, white, cartridge buff, and iron gray aerial mycelium, that in the substratum is clay color, tawny olive, and iron gray. An olivaceous black(3) pionnotes may be produced.

Oat agar.—Cultures 1 month old have a medium coarse, woolly, white and cartridge buff mycelium; a dusky dull green stroma may be present in places. Small and large sporodochia forming large heaps of pionnotes masses are present; they are pale pinkish buff and pinkish buff.

Rice.—Cultures 20 days old have a medium scant, matted mycelium that is white, cartridge buff, and chestnut brown. The rice is changed to shrimp pink or seashell pink. Small, bone brown sclerotia may be developed; warm buff, pinkish buff, salmon buff, flesh color, pale olive buff, deep Corinthian red, or vinaceous rufous sporodochia and pionnotes masses are produced. Cultures 1 month old are characterized by scant, white, aerial mycelium. On the rice it is Prussian red and ocher red, possibly in a ring. The rice itself is Etruscan red. The pion-

notes spore mass is pale pinkish buff, light pinkish cinnamon, or hydrangea pink. In older cultures, 2 months old, the mycelium changes to colonial buff, cameo brown, chocolate, or chestnut brown. The sporodochia and pionnotes masses have also become walnut brown and in some cases with orange vinaceous, apricot buff, light vinaceous cinnamon, or occasionally pale Niagara green. Upon addition of a 10 per cent solution of potassium hydroxide the plectenchymic mass and the liquid turn dusky violet, which is the alkaline color modification.

Potato-tuber plug.—Cultures 1 month old are characterized by a loose, medium coarse, granular, woolly, white to cartridge buff mycelium. It may also be leathery, and Saccardo's umber or Saccardo's brown in places. Spots of pistachio green and stromatic masses of dusky dull bluish green and deep delft blue may also be present. Small, spherical, Saccardo's umber or olive buff sclerotia may develop. The greater part of the plug may be covered with sporodochia and pionnotes masses that are usually warm buff, pinkish buff, olive buff, and tawny olive, but sometimes porcelain green, dark porcelain green, and dusky green-blue.(2) Older cultures are much the same as to the mycelium, but usually have more deep olive buff, Niagara green, terre-verte, glaucous green, and snuff brown sporodochia and pionnotes masses. The sclerotia may also be indigo blue.

Melilotus stem.—Cultures 1 month old have a loose, medium coarse, granular, woolly, white and cartridge buff mycelium. Mainly a pionnotes is produced over the stem with a few sporodochia. They are cream color and light buff, occasionally deep glaucous green. Blackish brown(3) sclerotia may develop.

Mature corn stalk.—Cultures 1 month old have a scant white to cream color mycelium. Bone brown sclerotia may be present. Warm buff and cinnamon buff, often with pale glaucous green, sporodochia and pionnotes masses are produced.

Banana peel.—Cultures 2 months old have a scant pinkish buff and cinnamon buff mycelium with cinnamon buff, olive buff, deep olive buff, and lichen green, light terre-verte, or Gobelín blue sporodochia and pionnotes masses.

Green bean pod.—Cultures 16 days old have a medium scant to thick, cartridge buff and cream buff mycelium. At this age the sporodochia and pionnotes masses are chamois and honey yellow. Three-month-old cultures have a medium scant, white to cartridge buff or cinnamon buff mycelium. It may be clay

color where it touches the glass. Sporodochia and pionnotes masses are scattered over the bean. They are warm buff, cream buff, cinnamon buff, olive buff, citrine drab, and light porcelain green to glaucous green. Some of the oldest may be mikado brown or Natal brown. Isabella color sclerotia may be present.

Banana fruit flesh.—Cultures 26 days old have a medium thin, matted mycelium that is white, pinkish buff, glaucous blue, and orient blue.

The color characters, especially of the spore masses, may be somewhat variable; that is, under some conditions the green may be present, and then under other conditions the same culture will not produce the green. There are two basic colors in the section *Martiella*; namely, light orange yellow and indigo blue. All other colors present are modifications of these; consequently a variety of colors, from yellow to blue, as pointed out in the above descriptions, can be obtained. The change in the color of the rice may also vary from seashell pink to Etruscan red.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 11 days old; conidia from sporodochia:

Conidia—

- 0-septate, 7 per cent, 12 by 4.25 (8 to 17 by 3.25 to 5) μ .
- 1-septate, 11 per cent, 19 by 5 (15 to 26 by 4 to 6) μ .
- 2-septate, 4 per cent, 27 by 5 (25 to 32 by 4.5 to 6) μ .
- 3-septate, 72 per cent, 36 by 5.5 (26 to 50 by 4.5 to 6) μ .
- 4-septate, 5 per cent, 48 by 5.5 (41 to 57 by 5.25 to 6) μ .
- 5-septate, 1 per cent, 52 by 5.5 (48 to 53 by 5.25 to 6) μ .

Hard potato agar; culture 20 days old; conidia from pionnotes:

Conidia—

- 3-septate, 71 per cent, 39 by 4.5 (23 to 52 by 3.75 to 5.75) μ .
- 4-septate, 23 per cent, 43 by 4.75 (31 to 51 by 4.5 to 5) μ .
- 5-septate, 6 per cent, 40 by 5 (35 to 53 by 4.25 to 5.5) μ .

Green bean pod; culture 11 days old; conidia from pionnotes:

Conidia—

- 0-septate, 2 per cent, 12 by 4.25 (8 to 14 by 3.25 to 5) μ .
- 1-septate, 3 per cent, 19 by 5 (16 to 23 by 3.5 to 6) μ .
- 2-septate, 3 per cent, 26 by 5.25 (22 to 29 by 4 to 5.5) μ .
- 3-septate, 85 per cent, 34 by 5.25 (22 to 41 by 4.5 to 6) μ .
- 4-septate, 7 per cent, 37 by 5.25 (32 to 43 by 4.5 to 6) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 76 per cent, 36 by 5 (22 to 52 by 3.75 to 6) μ .
- 4-septate, 12 per cent, 43 by 5 (32 to 57 by 4.5 to 6) μ .
- 5-septate, 3 per cent, 46 by 5.25 (35 to 53 by 4.25 to 6) μ .

MEASUREMENTS OF CHLAMYDOSPORES ON DIFFERENT MEDIA

Hard potato agar; culture 2 months old:

Chlamydospores—

0-septate, conidial, 100 per cent, 7.25 by 6.25 (5.5 to 9 by 5.5 to 7.25) μ .

1-septate, conidial.

0-septate, mycelial, 72 per cent, 8.5 by 8.5 (8 to 9 by 8 to 9) μ .

1-septate, mycelial, 18 per cent, 12 by 9 (9 to 9 by 9 to 14) μ .

Rice; culture 70 days old:

Chlamydospores—

0-septate, conidial, 100 per cent, 12 by 6 (10 to 14 by 6 to 6) μ .

1-septate, conidial.

0-septate, mycelial, 91 per cent, 10 by 10 (8 to 12 by 8 to 12) μ .

1-septate, mycelial, 9 per cent, 10 by 10 (8 to 12 by 8 to 12) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Chlamydospores:

0-septate, conidial, 100 per cent, 6 by 9.5 (5.5 to 7.25 by 5.5 to 14) μ .

1-septate, conidial.

0-septate, mycelial, 81 per cent, 9.25 by 9.25 (8 to 12 by 8 to 12) μ .

1-septate, mycelial, 19 per cent, 11 by 9.5 (8 to 14 by 8 to 12) μ .

Terminal and intercalary chlamydospores are produced. When young they are smooth, and when older rugose.

FUSARIUM MARTII Appel and Wollenweber var. **VIRIDE** Sherbakoff. Plate 5, figs. 5 to 8; text fig. 39.

Fusarium martii viride SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 247-249; WOLLENWEBER, Ann. Myc. 15 (1917) 26.

Sherbakoff's description is as follows:

Differs from *F. martii* by having macroconidia somewhat narrower and usually by a paler color of conidia and substratum; dark blue color of conidial masses not observed. Typical color of conidia in mass, on potato agar rich in glucose, pale smoke gray and substratum pale drab gray.

Habitat.—On rotted roots of citrus (*Citrus aurantifolia* Swingle) and in the soil. Tela and Trujillo, Honduras, Central America (*Reinking R 99*).

Fusarium martii var. *viride* is rather common in the soil, having been found in 3 per cent of the total soil isolations. This fungus is distributed also in Europe on *Solanum*, *Pisum*.

Pirus, and other plants. In England it has been proved to be a wound parasite causing apple-fruit rot in storage.¹⁰

It is a question whether or not this is a valid variety, as the variation in spore measurements and color characters in *F. martii* var. *minus* would cover the slight differences here observed.

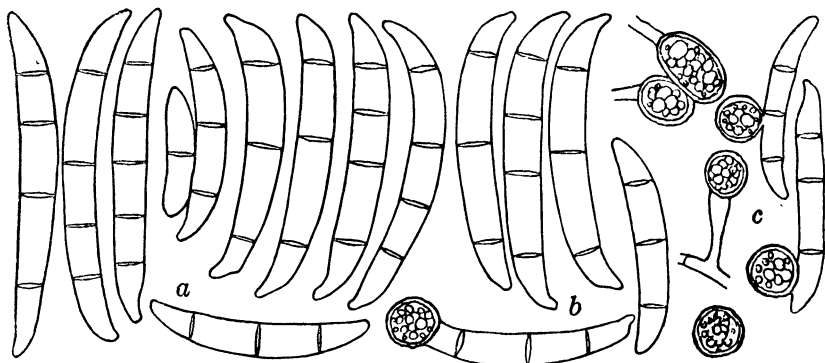


FIG. 39. *Fusarium martii* Appel and Wollenweber var. *viride* Sherbakoff; a, conidia from pionnotes of 7-day-old hard potato-agar culture; b, conidia from pionnotes of 7-day-old hard potato-agar culture; c, chlamydospores from 21-day-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

The growth characters on various media are very similar to those discussed under *F. martii* var. *minus*. The conidial masses may not be quite so dark blue, although this character is variable. The green coloration, especially in zonation, may be more marked in this variety.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 11 days old; conidia from pionnotes:

Conidia—

- 0-septate, 3 per cent, 12 by 4.25 (8 to 14 by 3.25 to 4.5) μ .
- 1-septate, 7 per cent, 19 by 4.5 (14 to 23 by 3.5 to 5.25) μ .
- 2-septate, 1 per cent, 25 by 5.25 (23 to 28 by 5 to 5.5) μ .
- 3-septate, 85 per cent, 38 by 5.25 (33 to 44 by 5 to 5.5) μ .
- 4-septate, 3 per cent, 41 by 5.5 (36 to 44 by 5.5) μ .
- 5-septate, 1 per cent, 41 by 5.5 μ .

Hard potato agar; culture 20 days old; conidia from pionnotes:

Conidia—

- 0-septate, 1 per cent, 12 by 3.5 (12 to 13 by 3.5 to 3.5) μ .
- 1-septate, 2 per cent, 19 by 4.75 (16 to 23 by 4.5 to 5) μ .
- 2-septate, 2 per cent, 23 by 5 μ .
- 3-septate, 79 per cent, 41 by 5.25 (33 to 48 by 5 to 5.5) μ .
- 4-septate, 14 per cent, 42 by 5 (35 to 49 by 4.5 to 5.5) μ .
- 5-septate, 2 per cent, 45 by 5 (39 to 50 by 4.5 to 5.5) μ .

¹⁰ Kidd, M. N., and A. Beaumont, Trans. Brit. Myc. Soc. 10 (1924) 116.

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 82 per cent, 40 by 5.25 (33 to 48 by 5 to 5.5) μ .

4-septate, 8 per cent, 42 by 5.25 (35 to 49 by 4.5 to 5.5) μ .

5-septate, 2 per cent, 43 by 5.25 (39 to 50 by 4.5 to 5.5) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Green bean pod; culture 45 days old:

Chlamydospores—

0-septate, conidial, 100 per cent, 7.25 by 6 (5.5 to 9 by 5.5 to 6.25) μ .

1-septate, conidial.

0-septate, mycelial, 88 per cent, 12 by 8 (9 to 14 by 7 to 9) μ .

1-septate, mycelial, 12 per cent, 17 by 9.5 (12 to 22 by 9 to 10) μ .

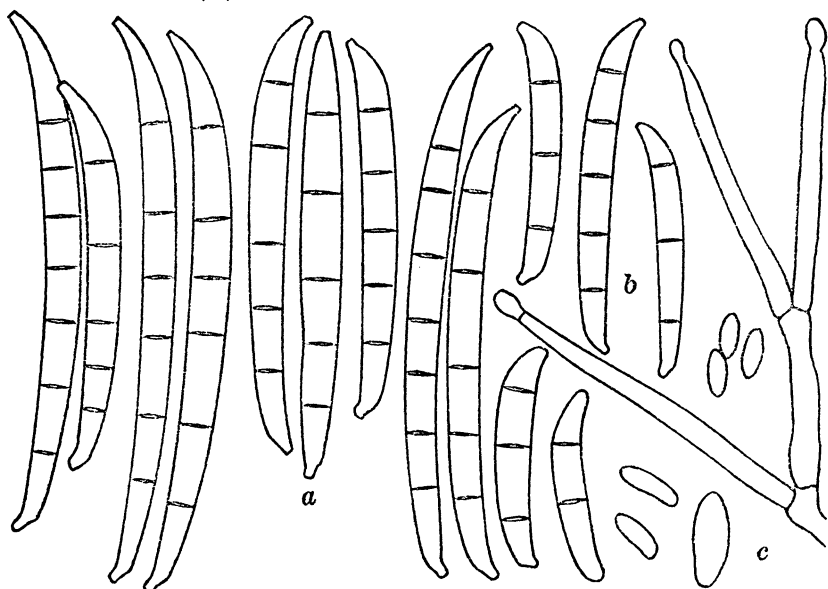


FIG. 40. *Fusarium martii* Appel and Wollenweber; a, conidia, typical, from pionnotes of 9-day-old potato-tuber plug culture; b, conidia, small type, from pionnotes of 23-day-old hard potato-agar culture; c, conidiophore from 8-day-old green bean-pod culture.

FUSARIUM MARTII Appel and Wollenweber. Text fig. 40.

Fusarium martii APPEL and WOLLENWEBER, Arb. Kais. Biol. Anst. f. Land- u. Forstw. 8 (1910) 78-84; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 244-247; WOLLENWEBER, Ann. Myc. 15 (1917) 25-26.

The original diagnosis of the fungus from Irish potatoes gives the following characters:

Conidia scattered in the mycelium, in false heads, or in sporodochia or pionnotes, normal conidia much longer than in

F. solani, straight in the middle or only slightly curved, curve somewhat more pronounced at the ends, especially the apex, dorsal and ventral sides almost parallel, except at the apex; 3- or 4-septate, 44 to 60 by 4.75 to 5.5 (39 to 70 by 4.5 to 6) μ ; less frequently 5-septate, 54 to 62 by 4.5 to 5.75 μ ; 6-septate, up to 82 by 5 μ ; color of conidial masses between brownish white and light brown and, through the mingling of the greenish blue plectenchymata, the pionnotes may assume a gray, bluish gray, or brown to black color; plectenchymatic stroma little or lacking; chlamydospores as in *F. solani*.

Habitat.—On rotted wild fig fruit (*Ficus* sp.) on ground and in the soil. Trujillo and Tela, Honduras, Central America (*Reinking R 91*).

Fusarium martii has been proved to cause apple-fruit rot in England.¹¹

GROWTH ON VARIOUS MEDIA

Growth characters on various media are similar to those discussed under *F. martii* var. *minus*.

MEASUREMENTS OF CONIDIA ON VARIOUS MEDIA

Hard potato agar; culture 11 days old; conidia from sporodochia:

Conidia—

- 0-septate, 4 per cent, 9 by 3.5 (9 to 10 by 3.5) μ .
- 1-septate, 4 per cent, 22 by 3.75 (21 to 23 by 3.5 to 4) μ .
- 2-septate, 2 per cent, 29 by 4.5 μ .
- 3-septate, 70 per cent, 34 by 4.75 (23 to 38 by 4.5 to 5.25) μ .
- 4-septate, 16 per cent, 37 by 4.75 (36 to 41 by 4.5 to 5) μ .
- 5-septate, 4 per cent, 41 by 5.25 (41 to 42 by 5 to 5.25) μ .

Potato-tuber plug; culture 9 days old; conidia from pionnotes:

Conidia—

- 4-septate, 2 per cent, 54 by 4.75 (48 to 60 by 4 to 5.5) μ .
- 5-septate, 58 per cent, 57 by 5 (50 to 63 by 4.5 to 5.5) μ .
- 6-septate, 31 per cent, 71 by 4.75 (70 to 73 by 4.5 to 5) μ .
- 7-septate, 9 per cent, 73 by 4.75 (70 to 76 by 4.5 to 5) μ .

Green bean pod; culture 90 days old; conidia from pionnotes:

Conidia—

- 0-septate, 19 per cent, 7 by 2.5 (5 to 9 by 2 to 2.75) μ .
- 1-septate, 2 per cent, 14 by 3.25 (14 to 15 by 3.25 to 3.5) μ .
- 2-septate.
- 3-septate, 21 per cent, 31 by 4.5 (21 to 39 by 4 to 5) μ .
- 4-septate, 26 per cent, 37 by 5.25 (28 to 41 by 4.5 to 6) μ .
- 5-septate, 32 per cent, 40 by 5.25 (36 to 42 by 5.25 to 5.5) μ .

¹¹ Kidd, M. N., and A. Beaumont, l. c.

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 30 per cent, 33 by 4.5 (21 to 39 by 4 to 5.25) μ .
- 4-septate, 15 per cent, 43 by 5 (28 to 60 by 4 to 6) μ .
- 5-septate, 31 per cent, 46 by 5.25 (36 to 63 by 4.5 to 5.5) μ .
- 6-septate, 10 per cent, 71 by 4.75 (70 to 73 by 4.5 to 5) μ .
- 7-septate, 3 per cent, 73 by 4.75 (70 to 76 by 4.5 to 5) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Green bean pod; culture 45 days old:

Chlamydospores—

- 0-septate, conidial, 100 per cent, 7.25 by 5.25 (7.5 to 8 by 4.5 to 6) μ .
- 1-septate, conidial.
- 0-septate, mycelial, 83 per cent, 8 by 8 (7 to 9 by 7 to 9) μ .
- 1-septate, mycelial, 17 per cent, 13 by 9 μ .

FUSARIUM VIRIDE (Lechm.) Wollenweber. Text fig. 41.

Fusarium viride WOLLENWEBER, Ann. Myc. 15 (1917) 26.

Conidia scattered in the mycelium, in false heads, or in sporodochia or pionnotes, normal conidia larger, especially broader, than *F. martii*, slightly curved, curve more pronounced at the ends, subpedicellate, 3- to 5-septate, 30 to 50 by 4.5 to 6 μ ; 3-septate, 35 by 5.5 μ ; 4-septate, 44 by 5.5 μ ; 5-septate, 46 by 5.5 μ ; conidial mass cream buff, olive buff, with green; bluish green plectenchymata may be present; chlamydospores smooth, and when older roughened, 9 to 10 μ in diameter.

Habitat.—In soil. Tela, Honduras, Central America (Reinking R 170).

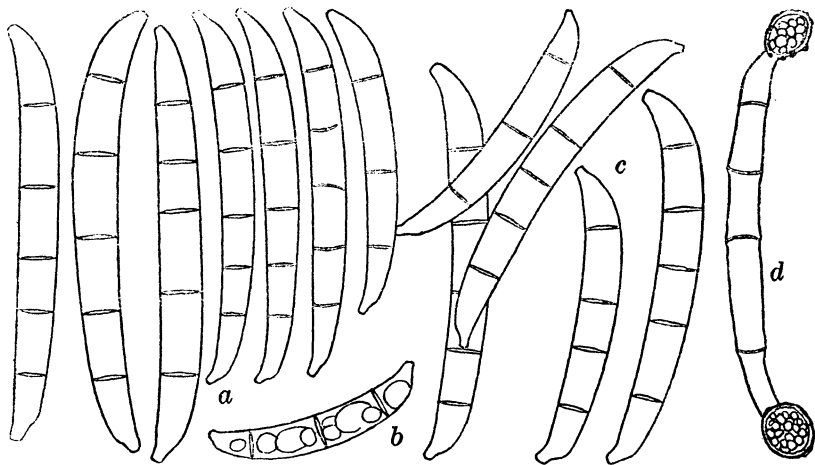


FIG. 41. *Fusarium viride* (Lechm.) Wollenweber; a, conidia from pionnotes of 3-month-old hard potato-agar culture; b, conidium from sporodochia of 21-day-old *Melilotus*-stem culture; c, conidia from pionnotes of 15-day-old potato-tuber plug culture; d, chlamydospores in conidium from 3-month-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a medium fine, powdery and woolly mycelium that is white, cartridge buff, ivory yellow, and cinnamon brown. Dusky dull bluish green lines may be present in the agar. Cream buff and pinkish buff sporodochia and pionnotes masses are produced. They may have a touch of Niagara green. Cultures 1 month old are the same, except that the separate pionnotes are in large masses and pinkish buff, deep olive buff, and dark olive buff. The mycelium in cultures 3 months old is cartridge buff with streaks of Saccardo's slate. The agar at the base of the slant may be cinnamon brown. The sporodochia and pionnotes masses are cream buff, Naples yellow with deep lichen green, and glaucous green. Plate cultures 1 month old have a medium fine, powdery, woolly, zonate at the edges, cartridge buff mycelium. A deep olive buff and light porcelain green pionnotes is usually present.

Oat agar.—Cultures 1 month old have a medium scant, aërial, white mycelium. Irregular, large, thick masses of pionnotes are produced over the slant, being made up of sporodochia. They are olive buff with touches of dark terre-verte.

Rice.—Cultures 20 days old have a medium fine, woolly, white, light buff, and Schoenfeld's purple mycelium. Few wartlike, Schoenfeld's purple sclerotia are produced. Some cream color sporodochia are present. The rice is turned coral pink. Cultures 1 month old may have spots of deep Corinthian red, and the rice may have turned Pompeiian red. Older cultures are practically the same, possibly with the addition of a deep vinaceous, leathery mycelium.

Potato-tuber plug.—One-month-old cultures have a scant, medium fine, woolly and matted mycelium that is white, cream color, deep olive, and often with wood brown. Cream buff, dark olive buff, heaped pionnotes masses are present over the plug. They may also have touches of Niagara green and glaucous green. Older cultures may have a Natal brown mycelium in places.

Melilotus stem.—Cultures 1 month old have a medium fine, woolly, white and cartridge buff mycelium. Heaped sporodochia and pionnotes masses are present in places over the stem and on top of the mycelium that is produced over the liquid at the base of the tube. They are cartridge buff and often with dusky green-blue.(2)

Green bean pod.—Cultures 2 months old have a medium thin, matted, ivory yellow mycelium, with large sporodochial masses that are pale olive buff to deep olive buff.

MEASUREMENTS OF CONIDIA ON VARIOUS MEDIA

Hard potato agar; culture 40 days old; conidia from pionnotes:

Conidia—

- 0-septate, 2 per cent, 13 by 4.5 (12 to 16 by 4.5) μ .
- 1-septate, 3 per cent, 20 by 4.75 (15 to 23 by 4.5 to 5.5) μ .
- 2-septate.
- 3-septate, 41 per cent, 41 by 5.5 (35 to 46 by 5.5) μ .
- 4-septate, 23 per cent, 45 by 5.5 (37 to 51 by 5.5 to 6) μ .
- 5-septate, 31 per cent, 50 by 5.5 (45 to 54 by 5.5 to 6) μ .

Green bean pod; culture 15 days old; conidia from pionnotes:

Conidia—

- 0-septate, 7 per cent, 12 by 4 (9 to 15 by 3.75 to 4) μ .
- 1-septate, 6 per cent, 20 by 4.75 (14 to 25 by 4.5 to 5) μ .
- 2-septate, 6 per cent, 28 by 5.25 (28 by 5 to 5.5) μ .
- 3-septate, 48 per cent, 39 by 5.25 (36 to 43 by 5 to 5.5) μ .
- 4-septate, 25 per cent, 44 by 5.75 (41 to 52 by 5.5 to 6) μ .
- 5-septate, 8 per cent, 45 by 6 (42 to 48 by 5.5 to 6.25) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 45 per cent, 40 by 5.25 (35 to 46 by 5 to 5.5) μ .
- 4-septate, 24 per cent, 45 by 5.5 (37 to 52 by 5.5 to 6) μ .
- 5-septate, 20 per cent, 48 by 5.75 (42 to 54 by 5.5 to 6.25) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Green bean pod; culture 45 days old:

Chlamydospores—

- 0-septate in mycelium, 77 per cent, 9.5 by 9.5 (9 to 10 by 9 to 10) μ .
- 1-septate in mycelium, 23 per cent.

FUSARIUM RADICICOLA Wollenweber. Text fig. 42.

Fusarium radiculicola WOLLENWEBER, Journ. Agr. Research 2 (1914) 257–258; SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 257–260; CARPENTER, Journ. Agr. Research 5 (1915) 205; WOLLENWEBER, Ann. Myc. 15 (1917) 26.

Conidia, comparatively slender, spindle- to sickle-shaped, slightly constricted at both ends, apiculate to subpedicellate at the base, normally 3-septate, may occur scattered in sporodochia or pionnotes, averaging 30 to 45 by 3.75 to 5 μ ; 25 per cent of the total number may be 4-septate; 5 per cent may be 5-septate and average 40 to 59 by 4 to 5.25 μ ; chlamydospores, 7 to 10 μ , agree with those of other species of the section *Martiella*.

Habitat.—In soil. Tela, Honduras, Central America (Reinking R 165).

The conidia of *F. radiculicola* are narrower than in *F. solani* and are shorter and have fewer septations than in *F. martii*. The plectenchymatic mycelium is olive colored on sterilized potato tuber, with all shades of green and brown. The organisms described by Sherbakoff(9) and later by Carpenter(5) do not agree in all particulars with the original description.

Fusarium radiculicola is the cause of a rot of potato tubers and sweet potatoes in the United States.

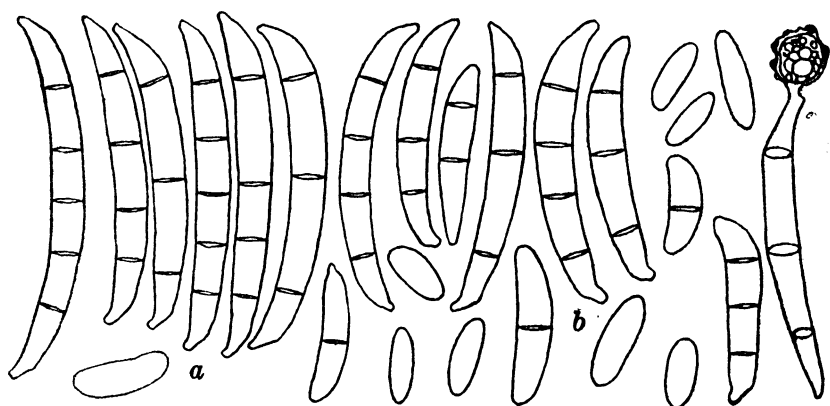


FIG. 42. *Fusarium radiculicola* Wollenweber; a, conidia from pionnotes of 15-day-old rice culture; b, conidia and chlamydo-spores from pionnotes of 3-month-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a medium coarse, woolly, white and ivory yellow mycelium. The agar is deep slate olive. Warm buff sporodochia are produced in heaps. In cultures 1 month old there is no change in the mycelium, but the sporodochia and pionnotes masses are in heaps, cream buff, olive buff, light terre-verte, and deep lichen green, and are generally in concentric rings over the slant. A characteristic snuff brown and bister ring is present at the edges of the agar on the side and base of the slant. Cultures 3 months old have a scant, woolly, cartridge buff mycelium with a cinnamon buff pionnotes in concentric rings. Characteristically the agar is turned to Natal brown and clove brown. On potato-agar plates, 1 month old, a medium coarse, woolly, white to cartridge buff mycelium is produced with a rather thin and dense cream color and pale olive buff to dark olive buff pionnotes in places under the mycelium.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a short, woolly, tiller buff, aerial mycelium, while that in the substratum is snuff brown and bister.

Oat agar.—Cultures 1 month old have a medium scant, woolly, white, aerial mycelium. Olive buff and pea green sporodochia in large heaps, gradually forming a pionnotes, are present over the slant. A mummy brown stromatic ring is usually present at the base of the slant.

Rice.—Cultures 19 days old have a medium scant, matted, rhodonite pink mycelium over the rice. Small, bister sclerotia may be present. Cultures 1 month old have a scant, medium fine, woolly, vinaceous pink, avellaneous, and wood brown mycelium. A pale pinkish buff pionnotes is generally produced. The top of the rice substratum is pinkish vinaceous, and lower it is light coral red.

Potato-tuber plug.—Cultures 20 days to 1 month old have a medium coarse, woolly, white, cartridge buff, and light buff mycelium that may also be sepia where it touches the glass. Pionnotes masses made up of sporodochia are present in small heaps. The younger are vinaceous buff, and the older deep olive buff or cinnamon buff, Saccardo's umber, and sepia. The potato cylinder is clove brown. Cultures 80 days old have a pale olive buff and clove brown mycelium that is matted and leathery in places. The pionnotes is olive buff, light terre-verte, and wood brown.

Melilotus stem.—Cultures 1 month old have a medium scant, coarse, woolly, white and cartridge buff mycelium. A thin, cream color and pale olive buff pionnotal growth is produced over the stem.

Green bean pod.—Cultures 1 month old are characterized by a medium dense, cartridge buff, cream buff, and pinkish buff mycelium. Abundant sporodochia and pionnotes masses, 0.5 to 3 mm in diameter and cinnamon buff to cinnamon, are present.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 2 months old; conidia from sporodochia:
Conidia—

0-septate.

1-septate, 4 per cent, 16 by 4.75 (14 to 17 by 4 to 5) μ .

2-septate, 3 per cent, 21 by 4.5 μ .

3-septate, 87 per cent, 32 by 4.5 (26 to 42 by 4 to 5) μ .

4-septate, 4 per cent, 39 by 5 (36 to 44 by 5) μ .

5-septate, 2 per cent, 46 by 4.5 (44 to 49 by 4.5) μ .

Green bean pod; culture 18 days old; conidia from sporodochia:

Conidia—

- 0-septate, 6 per cent, 11 by 3 (10 to 13 by 2.75 to 3.5) μ .
- 1-septate, 18 per cent, 15 by 4.25 (14 to 27 by 3.5 to 5) μ .
- 2-septate, 4 per cent, 24 by 4.5 (22 to 27 by 4.5 to 5) μ .
- 3-septate, 71 per cent, 32 by 5 (28 to 36 by 4.5 to 5.25) μ .
- 4-septate, 1 per cent, 41 by 4.5 μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 79 per cent, 32 by 4.75 (26 to 44 by 4.5 to 5.25) μ .
- 4-septate, 3 per cent, 40 by 4.75 (36 to 44 by 4.5 to 5) μ .
- 5-septate, 1 per cent, 46 by 4.5 (44 to 49 by 4.5) μ .

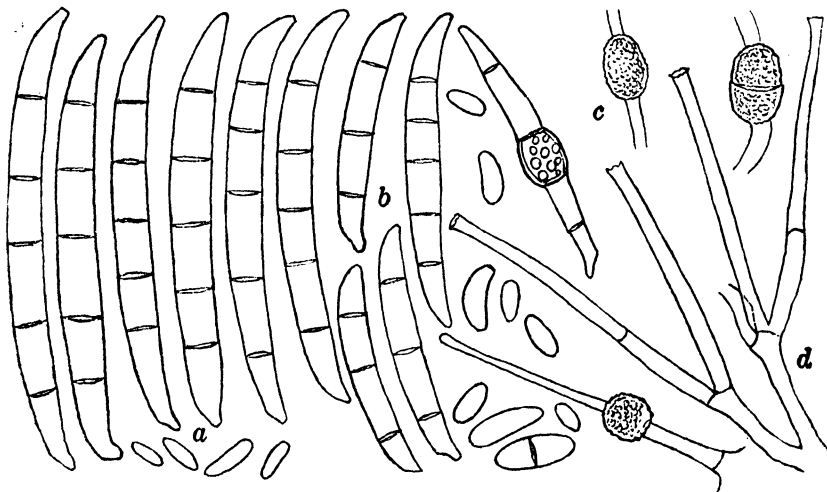


FIG. 48. *Fusarium striatum* Sherbakoff; a, conidia from pionnotes of 18-day-old potato-tuber plug culture; b, conidia from pionnotes of 16-day-old oatmeal-agar culture; c, chlamydospores from 14-day-old potato-tuber plug culture; d, conidiophore from mycelium of 23-day-old green bean-pod culture.

FUSARIUM STRIATUM Sherbakoff. Text fig. 43.

Fusarium striatum SHERBAKOFF, N. Y. (Cornell) Agr. Exp. Sta. Memoir No. 6 (1915) 255-257; WOLLENWEBER, Ann. Myc. 15 (1917) 25.

Sherbakoff's description is as follows:

Microconidia, at least on aërial mycelium, always present. Macroconidia of shape and septation intermediate between *F. martii* and *F. solani*, mostly 3-septate, 34.7 by 4.6 (31 to 36 by 4.4 to 5) μ , from colorless to yellowish glaucous and pale turquoise green, in numerous minute sporodochia; sporodochia often converging into a pseudopionnotes; aërial mycelium short (rarely up to 3 millimeters high), typically (on various agars) fine, uniformly from loose to very loose, downy in appearance,

from white to grayish white, substratum, on agars rich in glucose, from pale glaucous green to tawny olive and sepia. Cause of a tuber rot, striate in appearance, of *Solanum tuberosum* Linnæus.

Habitat.—On rotted papaya fruit and rotted tip of living papaya stem (*Carica papaya* Linnæus) (R 81) and in the soil. Tela, Honduras, Central America (*Reinking* R 81).

We found a greater percentage of 4- and 5-septate conidia than was reported by Sherbakoff.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by medium scant, coarse, woolly, tufted and powdery in places, cartridge buff, cream buff, and pinkish buff mycelium. Concentric rings of dusky dull bluish green may be present in the agar and also streaks of Saccardo's slate. A buckthorn brown ring is generally produced at the edges of the agar. Ochraceous buff sporodochia may be produced here and there. Cultures 1 month old have the same type of mycelium, except for being a little more dense and having a cinnamon buff pionnotes. Citrine drab streaks may be present in the agar, and the medium may turn sayal brown in places. Potato-agar plate cultures 1 month old have a medium coarse, short woolly, usually radiate and zonate cartridge buff mycelium. Antimony yellow pionnotes masses may be present. A plectenchymic mass of mycelium that is deep glaucous green and light porcelain green is frequently formed.

Potato-agar plate, 5 per cent dextrose.—Growth 1 month old is characterized by a scant, short, woolly, cartridge buff and deep grayish olive mycelium that may be in concentric rings. The mycelium in the substratum is russet vinaceous or dull greenish black.⁽¹⁾

Oat agar.—Cultures 1 month old have an aërial mycelium that is short, woolly, and white to cartridge buff with patches of stroma that are dark Prussian green and deep delft blue. Cinnamon buff, heaped sporodochia producing pionnotes masses are present.

Rice.—Cultures 20 days old have a scant white mycelium. The rice is colored seashell pink, rufous, and apricot orange. Vinaceous sporodochia are formed in small masses. Cultures 1 month old have a dense, woolly, tufted in places, white, light buff, warm buff, pale grayish vinaceous, Hay's brown, and light seal brown mycelium. A light ochraceous salmon and pale

ochraceous buff pionnotes is produced. The rice substratum is flesh color, vinaceous brown, rufous, and apricot orange.

Potato-tuber plug.—Cultures 18 days old have a medium scant, white to cartridge buff mycelium with masses of sporodochia that are cream buff when young and light terre-verte, dusky green-blue(1) to dark chessylite blue when older. Cultures 1 month old have the same type of mycelium, but the sporodochia and pionnotes usually are tilleul buff, pale olive buff, and terre-verte or dusky bluish green. In older cultures, up to 80 days old, the pionnotes masses may be dark Gobelin blue or dusky dull bluish green.

Melilotus stem.—Growth 1 month old is characterized by a scant, medium fine, woolly, cartridge buff mycelium. Few cream buff, pinkish buff, or citrine drab sporodochia may be present.

Green bean pod.—Cultures 2 months old have a scant, thin, matted, cartridge buff, chamois, pale pinkish buff, pinkish buff, and cinnamon buff mycelium. Cinnamon buff and clay color sclerotia may be present. Cinnamon buff sporodochia are produced sometimes over the sclerotia when present.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 11 days old; conidia from sporodochia:

Conidia—

0-septate, 17 per cent, 9 by 3.5 (6 to 11 by 2 to 5) μ .

1-septate, 6 per cent, 17 by 3.75 (14 to 23 by 3.25 to 5) μ .

2-septate, 3 per cent, 25 by 4.5 (23 to 26 by 4 to 4.5) μ .

3-septate, 43 per cent, 35 by 4.5 (27 to 41 by 4 to 5) μ .

4-septate, 25 per cent, 41 by 4.75 (36 to 46 by 4.5 to 5) μ .

5-septate, 6 per cent, 42 by 5 (41 to 45 by 5 to 5.25) μ .

Potato-tuber plug; culture 18 days old; conidia from pionnotes:

Conidia—

3-septate, 24 per cent, 35 by 4.25 (33 to 37 by 4 to 4.5) μ .

4-septate, 42 per cent, 43 by 4.5 (40 to 47 by 4 to 5) μ .

5-septate, 34 per cent, 53 by 4.5 (46 to 61 by 4 to 5) μ .

Melilotus stem; culture 20 days old; conidia from sporodochia:

Conidia—

3-septate, 30 per cent, 31 by 3.75 (27 to 35 by 3.5 to 3.75) μ .

4-septate, 48 per cent, 41 by 3.75 (35 to 47 by 3.5 to 5) μ .

5-septate, 22 per cent, 43 by 4.25 (30 to 51 by 4 to 4.5) μ .

Green bean pod; culture 9 days old; conidia from sporodochia:

Conidia—

0-septate, 30 per cent, 8 by 3.25 (6 to 9 by 2.75 to 3.5) μ .

1-septate, 2 per cent, 18 by 3.25 (4 to 21 by 3.25) μ .

2-septate, 1 per cent, 23 by 4 μ .

3-septate, 35 per cent, 34 by 4.75 (26 to 38 by 4 to 5) μ .

4-septate, 21 per cent, 38 by 4.75 (35 to 43 by 4.5 to 5) μ .

5-septate, 11 per cent, 43 by 5 (40 to 48 by 5 to 5.25) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 33 per cent, 34 by 4.25 (26 to 41 by 3.5 to 5) μ .

4-septate, 34 per cent, 41 by 4.5 (35 to 47 by 3.5 to 5) μ .

5-septate, 18 per cent, 45 by 4.75 (30 to 61 by 4 to 5.25) μ .

FUSARIUM JAVANICUM Koorders. Text fig. 44.

Fusarium javanicum KOORDERS, Vern. Koninkl. Akad. Wetensch. Amsterdam II 13 (1907) 247; SACCARDO, Syll. Fung. 22 (1913) 1482; WOLLENWEBER, Ann. Myc. 15 (1917) 26; Ber. der Deutsch. Bot. Gesell. 35 (1918) 742.

Conidia scattered, in sporodochia and pionnotes, 3-, 4- (5-) septate, 43 to 54 by 4.5 to 5 μ ; 5-septate, 49 to 54 by 4.5 to 5.25 μ ; base subpedicellate, apex cell longer and less curved and

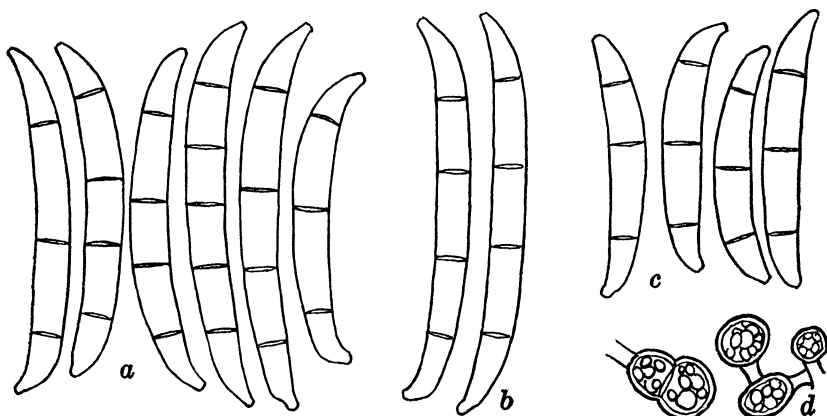


FIG. 44. *Fusarium javanicum* Koorders; a, conidia from pionnotes of 24-day-old hard potato-agar culture; b, conidia from pionnotes of 17-day-old rice culture; c, conidia from sporodochia of 18-day-old *Melilotus*-stem culture; d, chlamydospores from 16-day-old hard potato-agar culture.

more pointed than in the preceding species, sometimes acute, approaching sickle-shaped; chlamydospores 1-celled, 2-celled, terminal and intercalary; mycelium white to cartridge buff; conidial masses cream buff, olive ocher, or at times greenish.

Conidia may be the imperfect stage of a *Hypomyces*.

Habitat.—In soil. Tela, Honduras, Central America (*Reinking R 161*).

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a scant, white, cream buff and ivory yellow mycelium, often with a dusky dull bluish green line in the agar and a Dresden brown ring at the base. Concentric rings of cream buff or pinkish buff sporodochia are present. One-month-old growth

has a fine, woolly, matted, but not dense, white and cartridge buff mycelium. Heaped pionnotal masses that are cream buff, cinnamon buff, often with a little glaucous green, are generally formed. The characteristic mummy brown strip is produced at the base and sides of the slant. Cultures 3 months old are very much the same with the pionnotes more of a dark olive buff, and the agar may have turned Hay's brown at the base. Plate cultures 1 month old have a fine, woolly, white and cartridge buff mycelium with a cream buff pionnotes about the point of transfer.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a scant, woolly, cartridge buff, aërial mycelium, while that in the substratum is tawny olive. Citrine drab pionnotes masses may be produced in places.

Oat agar.—Cultures 1 month old are characterized by a medium fine, woolly, white mycelium. A mummy brown ring is usually present at the base of the slant. Cartridge buff, Isabella color, and pale olive buff pionnotes masses made up of sporodochia are present.

Rice.—Cultures 20 days old have a scant, white and pale grayish vinaceous mycelium that may be bone brown and leathery in places. Small, Natal brown and bone brown sclerotia are sometimes formed. Avellaneous sporodochia are produced on top of the rice. One-month-old growth has a fine, woolly, white mycelium with a pale pinkish cinnamon pionnotes. The rice substratum is pale flesh color. Cultures 2 months old have a matted, leathery, cartridge buff, vinaceous drab, and deep purplish vinaceous mycelium, possibly with spots of light seal brown. Vinaceous drab sclerotia may be present. The pionnotes masses are pale grayish vinaceous and tilleul buff. The rice substratum is shrimp pink.

Potato-tuber plug.—Cultures 20 days old are characterized by a scant white, cream color and cinnamon buff mycelium. Ivory yellow, warm buff, pinkish buff, olive buff, and snuff brown pionnotes masses are usually present. Cultures 1 month old have a scant, fine, woolly, white and cinnamon buff mycelium with cream buff, buffy brown, vinaceous russet, and dark olive pionnotes masses composed of sporodochia. Still older cultures, up to 80 days old, have a scant, cartridge buff to cinnamon buff mycelium with honey yellow, cinnamon buff, snuff brown, dark olive buff, Niagara green, and dark terre-verte pionnotes masses.

Melilotus stem.—One-month-old growth has a fine, woolly, cartridge buff mycelium with pinkish buff, streaked with deep

glaucous green sporodochia and heaped pionnotes masses over the stem.

Green bean pod.—Cultures 2 months old have a thin, matted, white, cartridge buff to pinkish buff mycelium with pinkish buff, cinnamon buff, and orange cinnamon sporodochia, 1 to 2 mm in diameter, and pionnotes masses.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 18 days old; conidia from sporodochia:

Conidia—

- 1-septate, 6 per cent, 20 by 4.75 (19 to 20 by 4.5 to 5) μ .
- 2-septate, 4 per cent, 23 by 5.25 (17 to 28 by 5 to 5.5) μ .
- 3-septate, 75 per cent, 42 by 5.5 (39 to 47 by 5 to 6) μ .
- 4-septate, 15 per cent, 46 by 5.5 (42 to 52 by 5 to 6) μ .

Green bean pod; culture 7 days old; conidia from sporodochia:

Conidia—

- 0-septate, 2 per cent, 12 by 4 (10 to 15 by 3.25 to 4.5) μ .
- 1-septate, 10 per cent, 21 by 4.75 (18 to 23 by 4 to 5.25) μ .
- 2-septate, 3 per cent, 30 by 4.75 (26 to 33 by 4.5 to 6) μ .
- 3-septate, 82 per cent, 38 by 5.25 (24 to 45 by 4.5 to 5.5) μ .
- 4-septate, 3 per cent, 43 by 5.25 (40 to 45 by 4.5 to 6) μ .

Hard potato agar; culture 24 days old; conidia from pionnotes:

Conidia—

- 3-septate, 24 per cent, 41 by 4.75 (37 to 46 by 4.5 to 5) μ .
- 4-septate, 71 per cent, 49 by 5.25 (45 to 52 by 4.75 to 5.5) μ .
- 5-septate, 5 per cent, 49 by 5.25 (45 to 52 by 4.75 to 5.5) μ .

Potato tuber plug; culture 16 days old; conidia from pionnotes:

Conidia—

- 3-septate, 52 per cent, 33 by 4.75 (28 to 38 by 4 to 5.5) μ .
- 4-septate, 47 per cent.
- 5-septate, 1 per cent.

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

- 3-septate, 56 per cent, 39 by 5 (24 to 47 by 4 to 6) μ .
- 4-septate, 34 per cent, 45 by 5.25 (40 to 52 by 4.5 to 6) μ .
- 5-septate, 2 per cent, 49 by 5.25 (45 to 42 by 4.75 to 5.5) μ .

FUSARIUM THEOBROMAE Appel and Strunk (synonym *Fusarium heveae* P. Hennings), Text fig. 45.

Fusarium theobromae APPEL and STRUNK, Centr. F. Bact. Par. II, Abt. 11 (1904) 635–637; APPEL and WOLLENWEBER, Arb. Kais. Biol. Anst. f. Land- u. Forstw. 8 (1910) 160, Abb. 90, D1 Taf. 2, 98 f.; WOLLENWEBER and REINKING, Phytopath. 15 (1925) 168.

Stroma plectenchymic, ochraceous white, sometimes olive to greenish blue, aerial mycelium cream white, caespitose, conidia mostly scattered, more seldom in sporodochia, cream color in masses, elongate, slightly curved, pedicellate 3- to 5-septate; 3-septate, 28 to 46 by 3.5 to 5 μ ; 5-septate, 44 to 60 by 4 to 5.5

μ ; very rarely 6-septate, 52 to 73 by 4.5 to 5.5 μ ; ¹² in aërial mycelium also smaller conidia, mostly unicellular ovoid, 6 to 12 by 2.5 to 3.5 μ ; chlamydospores globose or pear-shaped, terminal and intercalary, 1-celled, 2-celled, or in clusters, 5 to 8 μ in diameter.

Conidia may be the imperfect stage of a *Hypomyces*.

Habitat.—In soil. Trujillo and Tela, Honduras, Central America (*Reinking R 129*).

Fusarium theobromae has been reported as the cause of pod rot of cacao in various parts of the world.

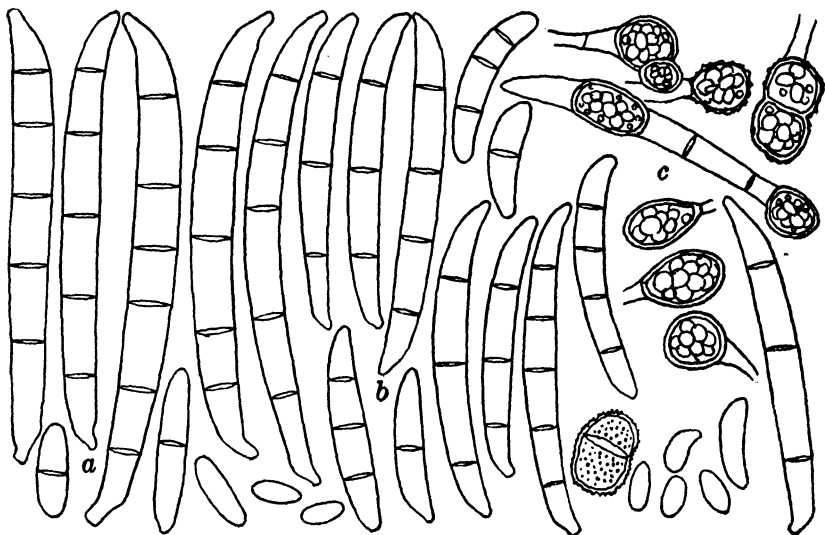


FIG. 45. *Fusarium theobromae* Appel and Strunk; a, conidia from mycelium of 1-month-old oatmeal-agar culture; b, conidia from mycelium of 15-day-old hard potato-agar culture; c, chlamydospores from 1-month-old hard potato-agar culture.

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a scant, medium fine, cottony, white, ivory yellow, cartridge buff, or cream buff mycelium. A buckthorn brown ring may develop at the base of the slant adjoining the glass. The agar may be deep glaucous green in a few spots. Seldom cream buff, with olive buff, and possibly glaucous green sporodochia are developed. Older cultures, 45 days old, have a scant, cartridge buff and ivory yellow mycelium with a Dresden brown ring at

¹² Conidia, according to the diagnosis of Appel and Strunk, are pluri-septate, 45 to 75 by 5 to 7 μ , while according to Wollenweber, cf. *Fus. aut. del. 428*, they are 4- to -6 (3- to 7-) septate, 39 to 60 by 4.5 to 5.25 μ .

the base of the slant. Sporodochia when present are terreverte. On potato agar plates 2 months old a very short, woolly, white to cartridge buff mycelium is found.

Potato-agar plate, 5 per cent dextrose.—Cultures 1 month old have a scant, aërial, light brownish vinaceous mycelium that in the substratum is vinaceous brown.

Oat agar.—Cultures 1 month old have a medium scant, white and cartridge buff aërial mycelium. Generally no fruiting bodies are formed.

Rice.—Cultures 20 days old are characterized by a scant, white and ochraceous tawny mycelium with pallid vinaceous drab in places. The rice is turned buff pink. Small, wartlike, warm buff sclerotia may develop. Cultures 2 months old have a scant mycelium that is cartridge buff, warm buff, and amber yellow and leathery in places, possibly with spots of Verona brown and vinaceous cinnamon. The rice is shrimp pink. Small warm buff sclerotia may be present. Spore bodies are generally not produced.

Potato-tuber plug.—Cultures 21 days old have a thin, furlike, aërial, white mycelium, often with a plectenchymic stroma of dusky green-blue.(2) It may be sepia and leathery where it touches the glass or light yellowish olive. Small, wartlike, Vandyke brown sclerotia may be present. Older cultures are practically the same, possibly with a change in the plectenchymic stroma to deep delft blue and in the sclerotia to black.

Melilotus stem.—Growth 23 days old is characterized by a medium dense, matted, cartridge buff mycelium over the stem. Generally no fruiting bodies are developed.

Green bean pod.—Cultures 2 months old have a thin, matted, cartridge buff or cream buff mycelium, sometimes with cartridge buff to cream buff sporodochia, and sclerotia that are blackish brown(3) or deep delft blue.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 11 days old; conidia from pionnotes:

Conidia—

- 0-septate, 2 per cent, 9 by 3.25 (9 to 10 by 3.25) μ .
- 1-septate, 5 per cent, 18 by 3.75 (14 to 22 by 2.75 to 4.5) μ .
- 2-septate, 2 per cent, 26 by 4 (25 to 27 by 3.5 to 4.5) μ .
- 3-septate, 31 per cent, 31 by 4 (24 to 37 by 3.25 to 5) μ .
- 4-septate, 55 per cent, 44 by 5 (26 to 57 by 3.5 to 5.5) μ .
- 5-septate, 5 per cent, 47 by 4.5 (31 to 63 by 3.5 to 5.5) μ .
- 6-septate, rare, 47 by 4 μ .

Hard potato agar; culture 12 days old; conidia from mycelium:

Conidia—

0-septate, 39 per cent.

1-septate, 24 per cent.

2-septate.

3-septate, 25 per cent, 37 by 4.25 (28 to 46 by 4 to 4.5) μ .

4-septate, 9 per cent, 47 by 4.25 (44 to 52 by 4 to 4.5) μ .

5-septate, 3 per cent, 51 by 4.25 (44 to 59 by 4 to 4.5) μ .

6-septate, rare, 66 by 4.75 (60 to 73 by 4.5 to 5) μ .

Oat agar; culture 1 month old; conidia from mycelium:

Conidia—

3-septate, 4 per cent.

4-septate, 33 per cent.

5-septate, 61 per cent, 53 by 5 (47 to 60 by 4.5 to 5.5) μ .

6-septate, 1 per cent.

7-septate, 1 per cent, 52 by 5.5 μ .

Green bean pod; culture 36 days old; conidia from mycelium:

Conidia—

0-septate, 75 per cent, 11 by 3.75 (7 to 12 by 2.75 to 4.5) μ .

1-septate, 19 per cent, 17 by 4.5 (14 to 20 by 4.5) μ .

2-septate, 1 per cent, 23 by 5 μ .

3-septate, 4 per cent, 28 by 4.75 (24 to 32 by 4.5 to 6) μ .

4-septate, 1 per cent, 41 by 4.5 (39 to 41 by 4.5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 20 per cent, 32 by 4.25 (24 to 46 by 3.25 to 6) μ .

4-septate, 22 per cent, 44 by 4.5 (26 to 57 by 3.5 to 6.5) μ .

5-septate, 3 per cent, 50 by 4.5 (31 to 63 by 3.5 to 5.5) μ .

6-septate, rare, 56 by 4.5 (47 to 73 by 4 to 5) μ .

7-septate, rare, 52 by 5.5 μ .

FUSARIUM ENSIFORME Wollenweber and Reinking. Plate 2, fig. 9; text fig. 46.

Fusarium ensiforme WOLLENWEBER and REINKING, *Phytopath.* 15 (1925) 169.

Stroma erumpent, sclerotia rugose, often dark blue; conidia in sporodochia and in pionnotes, from whitish to golden yellow, elongate, slightly sickle-shaped, somewhat constricted at the top end, distinctly pedicellate at the base, 5-, 6-, (3- to 7-) septate, 55 to 72 by 4.5 to 5 μ ; 7-septate, 69 to 81 by 4.75 to 5 μ ; 4-septate, 43 to 60 by 4 to 5 μ ; 3-septate, 37 to 50 by 3.75 to 5 μ ; in aerial mycelium also smaller, mostly unicellular, ovoid or slightly curved, 5 to 12 by 2.5 to 4 μ ; chlamydospores terminal or intercalary, 1- or 2-celled, sometimes rugose, 6 to 9 μ in diameter.

Conidia may be the imperfect stage of a *Hypomyces*.

Habitat.—On decaying fruit of wild fig (*Ficus* sp.) in virgin forest. Tela, Honduras, Central America (*Reinking R* 88).

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a thin, matted, ivory yellow mycelium, possibly with patches of Lumiere blue at the base of the slant. Older cultures, up to 3 months of age, have a similar appearance, but often with a deep orient blue stroma in places. The agar in spots may have changed to dark grayish blue-green. Plate cultures 2 months old have a short, woolly, white mycelium that usually is in concentric rings. A terre-verte stroma may be present in the center of the plate.

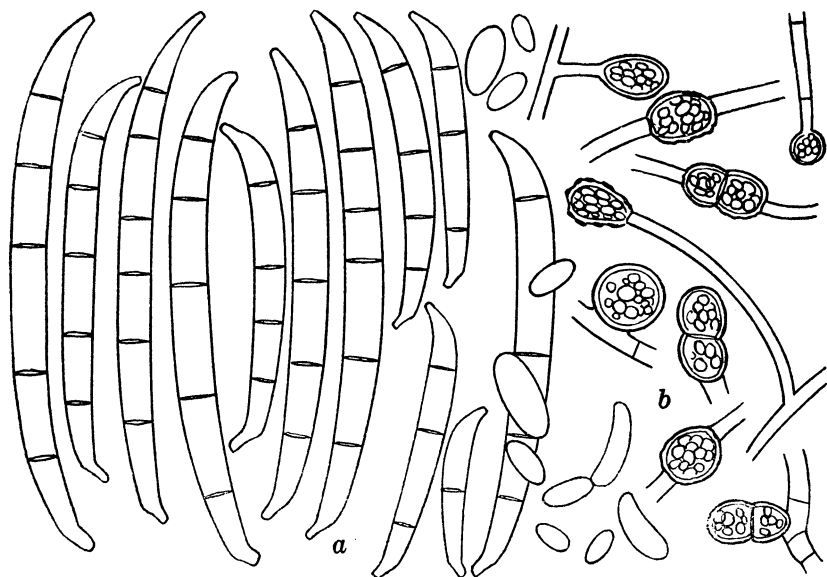


FIG. 46. *Fusarium ensiforme* Wollenweber and Reinking; a, conidia from sporodochia of 14-day-old *Alnus*-stem culture; b, chlamydospores from 14-day-old water culture.

Oat agar.—Twenty-day-old cultures have a thick, dense felty, pale pinkish buff mycelium, occasionally with spots of blackish brown.⁽³⁾ Dark delft blue sclerotia, 1 to 2 mm, are produced over the slant.

Rice.—Cultures 20 days old have a scant, white mycelium with the top of the rice turned apricot orange. Two-month-old cultures have a thin, matted, cartridge buff, apricot buff, apricot orange, and rufous mycelium. The rice is ochraceous orange and yellow ocher. Large, wartlike heaps of blackish brown⁽¹⁾ sclerotia may be present.

Potato-tuber plug.—Cultures 24 days old have a medium scant, white mycelium that may be in felty tufts in places and an invisible green in spots. Eight-day-old cultures are characterized by a matted, felty, cartridge buff mycelium with invisible green in places at the base.

Melilotus stem.—Twenty-day-old cultures have a medium dense, woolly, pale pinkish buff and cream buff mycelium over the stems. Small, cinnamon buff and clay color sporodochia, sometimes in masses, forming a pionnotes are produced.

Alnus stem.—Ten-day-old cultures have a medium scant, pale pinkish buff mycelium with small cinnamon buff sporodochia.

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Melilotus stem; culture 10 days old; conidia from pionnotes:

Conidia—

0-septate, 3 per cent, 9 by 3.25 (6 to 12 by 2.5 to 5) μ .

1-septate, 6 per cent.

2-septate, 1 per cent.

3-septate, 22 per cent, 41 by 4 (37 to 45 by 3.75 to 4.25) μ .

4-septate, 37 per cent, 48 by 4.25 (43 to 54 by 4 to 4.5) μ .

5-septate, 31 per cent, 66 by 4.75 (60 to 72 by 4.5 to 5) μ .

Alnus stem; culture 10 days old; conidia from sporodochia:

Conidia—

3-septate, 2 per cent, 43 by 4.5 (40 to 47 by 4.25 to 5) μ .

4-septate, 4 per cent, 50 by 4.5 (44 to 56 by 4.25 to 5) μ .

5-septate, 55 per cent, 60 by 4.75 (55 to 66 by 4.5 to 5) μ .

6-septate, 37 per cent, 67 by 5 (64 to 71 by 5) μ .

7-septate, 2 per cent, 75 by 4.75 (69 to 81 by 4.75 to 5) μ .

Green bean pod; culture 12 days old; conidia from sporodochia:

Conidia—

0-septate, 32 per cent, 9 by 3 (6 to 12 by 2 to 4.5) μ .

1-septate, 8 per cent, 23 by 4 (23 to 24 by 3.5 to 4.5) μ .

2-septate, 1 per cent, 31 by 4 μ .

3-septate, 9 per cent, 47 by 4.5 (43 to 50 by 4.5 to 5) μ .

4-septate, 37 per cent, 55 by 4.5 (45 to 60 by 4 to 5) μ .

5-septate, 12 per cent, 62 by 5 (59 to 66 by 4.5 to 5) μ .

6-septate, 1 per cent, 63 by 5 μ .

Frequently on oat agar and other agars, 99 per cent of the spores are microconidia.

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 11 per cent, 44 by 4.25 (37 to 50 by 3.75 to 5) μ .

4-septate, 26 per cent, 51 by 4.5 (43 to 60 by 4 to 5) μ .

5-septate, 33 per cent, 63 by 4.75 (55 to 72 by 4.5 to 5) μ .

6-septate, 13 per cent, 65 by 5 (63 to 71 by 5) μ .

7-septate, 1 per cent, 75 by 4.75 (69 to 81 by 4.75 to 5) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Hard potato agar; 23 days old:

Chlamydospores—

0-septate, in mycelium, 70 per cent, 7.25 by 7.25 (5 to 9.5 by 5 to 9.5) μ .

1-septate, in mycelium, 30 per cent, 6.25 by 11.5 (6 to 6.5 by 10.5 to 12.5) μ .

HYPOCREALES

Genus HYPOMYCES (Fries) Tul.

HYPOMYCES IPOMOEAE (Halsted) Wollenweber. Text fig. 47.

Hypomyces ipomoeae WOLLENWEBER, Phytopath. 3 (1913) 34; Journ.

Agr. Research 2 (1914) 270; Ann. Myc. 15 (1917) 1-56; Angew.

Bot. Zeit. f. Erf. d. Nutzpfl. 6 (1924) 300-313.

Perithecial stage.—Perithecia scattered or gregarious, free on the surface of the host as well as embedded in mycelium or on a distinct plectenchymatic stroma, ovoid, subconical, sub-flask-shaped; averaging 225 to 375 by 175 to 300 μ . Peridium strongly verrucose, owing to protuberancelike projections of cell groups, red to reddish brown, except the almost colorless conical beak. A few paraphyses line the inner wall of the throat from the ascus ball to the ostiolum. Asci up to over a hundred in each perithecium, intermixed with a few more-celled paraphyses. Ascospores eight in one row, or irregularly in two rows, 2-celled, ovoid to ellipsoidal with wrinkled exospore, in mass brownish white; one septum, average size, 10 to 13 by 4.5 to 6 μ , undermoist, overripe condition slightly constricted at the septum.

Conidial stage.—Conidia scattered in sporodochia or pionotes, of nearly cylindrical shape at the septal zone, slightly pointed and curved at the ends, base pedicellate without a distinct heel. Conidia, 3- to 5-septate; 3-septate, 30 to 45 by 3.75 to 5 μ ; 5-septate, 45 to 70 by 4.25 to 5.5 μ . Of the total number, 30 per cent may be 6-septate, 10 per cent may be 7-septate, with an average size up to 70 by 6 μ . In young, moist, and hunger stages, unicellular conidia occur, averaging 6 to 12 by 3 to 4.75 μ . Color of conidia masses brownish white, occasionally impregnated with blue, a mycelium color, especially formed in the plectenchyma. Conidiophores verticillately branched. Chlamydospores globose or ellipsoidal, terminal and intercalated, mostly unicellular and scattered, average diameter, 7 to 10 μ .

Habitat.—On decaying wild plantain (*Plantago* sp.) and in the soil. Tela and Trujillo, Honduras, Central America (*Reinking R 167*).

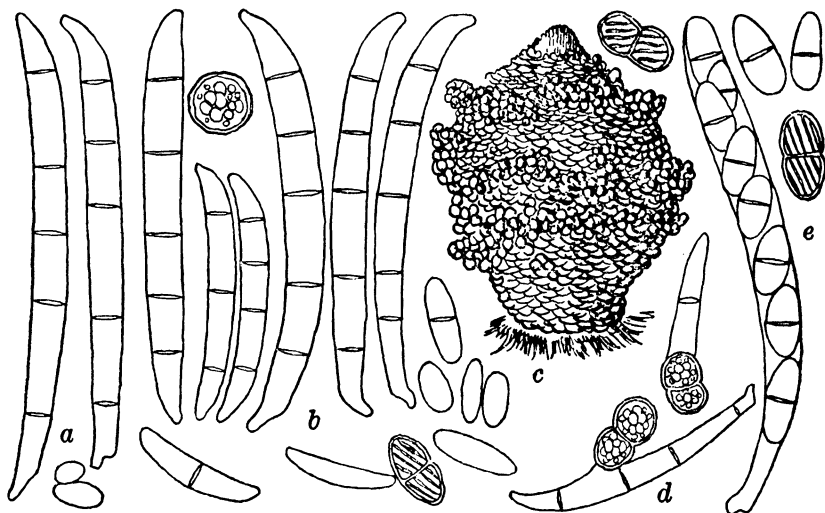


FIG. 47. *Hypomyces ipomoeae* (Halsted) Wollenweber; a, conidia from mycelium of 18-day-old potato-tuber plug culture; b, conidia from mycelium of 9-day-old hard potato-agar culture; c, perithecium, $\times 100$, from 20-day-old hard potato-agar culture; d, chlamydospores from 2-month-old hard potato-agar culture; e, ascus and ascospores from 10-day-old hard potato-agar culture.

Soil inoculations about banana plants failed to produce infection. (7)

GROWTH ON VARIOUS MEDIA

Hard potato agar.—Cultures 12 days old are characterized by a thin, matted, ivory yellow, buckthorn brown, and Dresden brown mycelium that has a stroma in concentric rings of dusky bluish green or Saccardo's slate. Few cream buff and chamois sporodochia may be present. Cultures 1 month old may have concentric rings of thin, matted, Saccardo's slate, dark grayish blue-green on pale olive buff mycelium. It may be greenish slate below with a few Russian green sporodochia. Cultures 2 months old and older are the same, but with the addition of brick red perithecia in places over the slant. Plate cultures 1 month old have a thin, white mycelium over the plate and frequently triangular stromatic patches of a dark bluish gray-green.

Potato-agar plate, 5 per cent dextrose.—One-month-old growth is characterized by a woolly, cartridge buff mycelium, possibly with hyssop violet at the edges. The mycelium in the substratum is in places dark bluish gray-green.

Note.—The somewhat variable conidial stage of *Hypomyces ipomoeae*, when isolated from different sources, fluctuates between *Fusarium theobromae* Appel and Strunk and *F. javani*-

cum Koorders, while the perfect stage in general has been found very constant in its characters.

A similar *Hypomyces*, recently collected on dead branches of an unknown tree and studied in pure culture, has been determined as *H. haematococcus* (Berkeley and Broome) Wollenweber (syn. *Nectria haematococca* Berkeley and Broome). It developed spores 12 to 13 by 5 to 6 (9 to 20 by 4 to 8) μ , slightly larger than those of *H. ipomoeae*, and conidia, 5- to 9-septate, 69 to 92 by 5.2 to 6.3 (47 to 102 by 4.5 to 7) μ , even larger and higher-septated than those in *Fusarium ensiforme* Wollenweber and Reinking, but similar in shape and color range. Perithecia occurred in pure culture at first very slowly, later on more readily, and agreed with those of the original host. This fungus will be studied further.

Oat agar.—Cultures 1 month old have a woolly, white to gray (deep gull gray) mycelium over the slant with small olivaceous black(3) sclerotia here and there. A mummy brown stromatic ring may be present at the base. Brick red or Morocco red perithecia are present.

Rice.—Cultures 20 days old have a medium growth of white, cartridge buff mycelium over the rice. In places it may be Mathews' purple and dark vinaceous purple. The rice is turned shrimp pink. Sclerotia, 3 mm in diameter and cinnamon buff, vinaceous brown, or dark vinaceous drab, are usually present. Cultures 1 month old have a matted, chestnut brown mycelium with occasional antimony yellow or Mars brown sporodochia and pionnotes masses. Cultures 2 months old may have a thin, matted mycelium that is Mars violet, cartridge buff, zinc orange, russet vinaceous, pale grayish vinaceous and on the glass ocher red or dull Indian purple. The rice remains shrimp pink.

Potato cylinder.—Cultures 23 days old have a medium dense, leathery, in places, white, cartridge buff, and grayish olive mycelium that also may be Prussian red and mummy brown where it touches the glass. It may also be dusky dull bluish green in places, and buffy olive stromatic folds may be present at the base. Cultures 2 months old have a leathery or thin papyry mycelial growth that is white to gray (pale gull gray), drab and cinnamon drab in places and blackish brown(1) and possibly dusky bluish green. Brick red or Morocco red perithecia are present, often in abundance.

Melilotus stem.—Two-month-old growth has a scant white, aërial mycelium and brick red and Morocco red perithecia in abundance over the stem.

Mature corn stalk.—Cultures up to 1 month old have a scant, fluffy, white and pinkish buff mycelium.

Banana peel.—Cultures 21 days old have a scant, pale pinkish cinnamon and light pinkish cinnamon mycelium in places with pale olive or buff sporodochia.

Banana fruit flesh.—A scant white and buff pink mycelium with black, wartlike sclerotia is produced after twenty-six days of growth.

Green bean pod.—Cultures 1 month old have a medium scant, cartridge buff and cinnamon buff mycelium with cinnamon buff and dark olive buff sporodochia. Acajou red and carmine perithecia are present in 2-month-old cultures.

MEASUREMENTS OF PERITHECIA

Hard potato agar; 2 months old:

Perithecia—

375 by 315 (330 to 450 by 250 to 350) μ .

MEASUREMENTS OF ASCOSPORES

Hard potato agar; 2 months old:

Ascospores—

11 by 4.5 (9 to 14 by 4 to 5.5) μ .

MEASUREMENTS OF CONIDIA ON DIFFERENT MEDIA

Hard potato agar; culture 10 days old; conidia from sporodochia:

Conidia—

0-septate, 12 per cent, 8 by 3.25 (7 to 9 by 2.25 to 3.5) μ .

1-septate, 8 per cent, 16 by 3.75 (16 by 3.25 to 4) μ .

2-septate, 3 per cent, 22 by 4.5 μ .

3-septate, 29 per cent, 37 by 4.75 (32 to 41 by 4.5 to 5) μ .

4-septate, 22 per cent, 45 by 5 (41 to 49 by 4.5 to 5.5) μ .

5-septate, 26 per cent, 50 by 4.75 (41 to 58 by 4 to 5.5) μ .

6-septate, rare, 63 by 4.25 (60 to 65 by 4 to 4.5) μ .

Green bean pod; culture 14 days old; conidia from mycelium:

Conidia—

0-septate, 39 per cent, 8 by 3.25 (5 to 13 by 2.25 to 4.5) μ .

1-septate, 13 per cent, 18 by 4 (15 to 23 by 3.5 to 4.5) μ .

2-septate, 3 per cent, 16 by 4.25 (13 to 20 by 4 to 4.5) μ .

3-septate, 40 per cent, 29 by 4.75 (24 to 34 by 4 to 5) μ .

4-septate, 5 per cent, 36 by 5 (33 to 39 by 5) μ .

AVERAGE OF THE ABOVE MEASUREMENTS

Conidia:

3-septate, 35 per cent, 33 by 4.75 (24 to 41 by 4 to 5) μ .

4-septate, 14 per cent, 41 by 5 (33 to 49 by 4.5 to 5.5) μ .

5-septate, 13 per cent, 50 by 4.75 (41 to 58 by 4 to 5.5) μ .

6-septate, rarer, 63 by 4.25 (60 to 65 by 4 to 4.5) μ .

MEASUREMENTS OF CHLAMYDOSPORES

Hard potato agar; culture 2 months old:

Chlamydospores—

0-septate, conidial, 6.25 by 5.75 (6 to 6.5 by 5.5 to 6) μ .

1-septate, mycelial, 11 by 6.5 (8.5 to 14 by 5.5 to 8.5) μ .

0-septate, mycelial, 7 by 7 (6.5 to 8 by 6.5 to 8) μ .

1-septate, mycel.al.

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ILLUSTRATIONS

PLATE 1

[Photomicrographs $\times 500$; half-tone reproduction about $\times 350$.]

- FIG. 1. *Fusarium dimerum* Penzig; spores from mycelium and pionnotes of oatmeal-agar culture; age, 28 days.
2. *Fusarium chlamydosporum* Wollenweber and Reinking; chlamydospores, microconidium, and swellings in hyphæ from mycelium on *Melilotus* stem and in water; age, 28 days.
3. *Fusarium semitectum* Berkeley and Ravenel; spores from mycelium of oatmeal-agar culture; age, 28 days.
4. *Fusarium camptoceras* Wollenweber and Reinking; spores from mycelium of oatmeal-agar culture; age, 28 days.
5. *Fusarium bullatum* Sherbakoff var. *minus* Wollenweber and Reinking; spores from pionnotes of oatmeal-agar culture; age, 28 days.
6. *Fusarium ossicolum* (Berkeley and Curtis) Saccardo; spores from pionnotes of oatmeal-agar culture; age, 28 days.
7. *Fusarium longipes* Wollenweber and Reinking; spores from pionnotes of oatmeal-agar culture; age, 27 days.
8. *Fusarium anthophilum* (A. Braun) Wollenweber; spores from mycelium of oatmeal-agar culture; age, 28 days.
9. *Fusarium moniliforme* Sheldon; spores from mycelium and pionnotes of oatmeal-agar culture; age, 27 days.
10. *Fusarium moniliforme* Sheldon var. *erumpens* Wollenweber and Reinking; spores from sporodochia and pionnotes of *Alnus*-stem culture; age, 50 days.
11. *Fusarium moniliforme* Sheldon var. *maius* Wollenweber and Reinking; spores from sporodochia and pionnotes of *Melilotus*-stem culture; age, 52 days.

PLATE 2

[Photomicrographs $\times 500$; half-tone reproduction about $\times 350$.]

- FIG. 1. *Fusarium fructigenum* Fries var. *maius* Wollenweber forma 1 Wollenweber and Reinking; spores from pionnotes of oatmeal-agar culture; age, 27 days.
2. *Fusarium decemcellulare* Brick; spores from large pionnotal masses of oatmeal-agar culture; age, 34 days.
3. *Fusarium macroceras* Wollenweber and Reinking; spores from pionnotes of oatmeal-agar culture; age, 23 days.
4. *Fusarium oxysporum* Schlechtendal emend. Wollenweber; macroconidia and chlamydospores; conidia from sporodochia and pionnotes of oatmeal-agar culture; age, 37 days. Chlamydospores from mycelium of oatmeal-agar culture; age, 28 days.

- FIG. 5. *Fusarium oxysporum* Schlechtendal var. *nicotianae* Johnson; spores from sporodochia and pionnotes of oatmeal-agar culture; age, 50 days.
6. *Fusarium cubense* Erwin F. Smith; spores from pionnotes of *Melilotus*-stem culture; age, 12 days.
 7. *Fusarium cubense* Erwin F. Smith; macroconidia, microconidia, and chlamydospores; conidia from pionnotes of *Melilotus*-stem culture; age, 12 days. Chlamydospores from mycelium of oatmeal-agar culture; age, 28 days.
 8. *Fusarium alluviale* Wollenweber and Reinking; macroconidia and chlamydospores; conidia from sporodochia and pionnotes of oatmeal-agar culture; age, 50 days. Chlamydospores from mycelium of oatmeal-agar culture; age, 28 days.
 9. *Fusarium ensiforme* Wollenweber and Reinking; spores from sporodochia of *Melilotus*-stem culture; age, 37 days.

PLATE 3. CULTURES OF PATHOGENIC FUSARIA ON VARIOUS MEDIA
IN TEST TUBES

- FIG. 1. *Fusarium cubense* Erwin F. Smith on hard potato agar; mycelium culture; age, 38 days.
2. *Fusarium cubense* Erwin F. Smith on hard potato agar; mycelium and pionnotes produced in culture; characteristic development of small blue sclerotia at the edges of growth near the base of the slant; age, 40 days.
 3. *Fusarium cubense* Erwin F. Smith on hard potato agar; mycelium and mass of sporodochia, forming pionnotes, produced in culture; few small, blue sclerotia present at the base; age, 37 days.
 4. *Fusarium cubense* Erwin F. Smith on potato-tuber plug; dense, leathery mycelium with small, blue sclerotia developed over potato-tuber plug; age, 136 days. Cotton in base of tube.
 5. *Fusarium cubense* Erwin F. Smith on green bean pod; mycelium and pionnotes development; age, 38 days. Cotton in base of tube.
 6. *Fusarium cubense* Erwin F. Smith on banana peel; mycelium, sporodochia, and pionnotes produced over the peel; age, 38 days. Cotton in base of tube.
 7. *Fusarium oxysporum* Schlechtendal var. *nicotianae* Johnson on hard potato agar; mycelium and mass of sporodochia, forming a pionnotes, produced in culture; characteristic large, blue sclerotia at the base of the slant; age, 38 days.
 8. *Fusarium oxysporum* Schlechtendal var. *nicotianae* Johnson on hard potato agar; mycelium culture with characteristic large, blue sclerotia at base; age, 38 days.

PLATE 4. CULTURES OF FUSARIA IN PETRI DISHES AND TEST TUBES

- FIG. 1. *Fusarium cubense* Erwin F. Smith on hard potato agar; fine, fluffy, cottony, white, light buff and pale ochraceous buff mycelial growth; age, 7 days.

- FIG. 2. *Fusarium martii* Appel and Wollenweber var. *minus* Sherbakoff on hard potato agar; medium coarse, short, woolly, pale pinkish buff and pinkish buff mycelium; zonation is also produced; age, 7 days.
3. *Fusarium martii* Appel and Wollenweber var. *minus* Sherbakoff on hard potato agar; medium coarse, dense, woolly, pale pinkish buff and pinkish buff mycelium; no real zonation; age, 7 days.
4. *Fusarium martii* Appel and Wollenweber var. *minus* Sherbakoff on hard potato agar; medium scant, coarse, woolly mycelium with mass of sporodochia forming a pionnotes; age, 39 days.
5. *Fusarium cubense* Erwin F. Smith on acidified hard potato agar; pure culture of fungus developing from portion of pseudostem of banana affected with wilt disease; age, 8 days.
6. *Fusarium martii* Appel and Wollenweber var. *minus* Sherbakoff on green bean pod; mycelium and pionnotes development; age, 39 days.

PLATE 5

FIGS. 1 to 4. *Calonectria rigidiuscula* (Berkeley and Broome) Saccardo; pure cultures of the fungus, isolated from partly decayed stems of *Hibiscus sabdariffae*, Buitenzorg, Java, by M. B. Schwarz, who stated that the fungus often follows *Phytophthora* stem rot. In pure culture on rice (fig. 1) the mycelium develops ocherous and carmine red plectenchymatic colors, while aërial hyphæ sometimes remain white. On oatmeal agar (fig. 2) the stroma is carmine red. Perithecia could be produced on stems of lupine and potato in a few weeks after transfer of rice-culture mycelium to these substrata. Figure 3 shows clusters of golden yellow perithecia on a lupine stem. Figure 4 shows the yellowish conidial masses developed in columns or tubercular forms at the surface of spherical or stilboidal sporodochia, scattered or in clusters, on an effuse carmine red or discolored plectenchymic stroma. Macroconidia (corresponding to *Fusarium decemcellulare*) and microconidia (*Spicaria colorans*) occur on most of the substrata used in pure cultures.

- 5 to 8. *Fusarium martii* Appel and Wollenweber var. *viride* Sherbakoff; pure cultures of the fungus, isolated from the soil, Tela, Honduras; fig. 5, on rice; fig. 6, on potato agar; fig. 7, on potato slant; fig. 8, on barley ear. The blue-green pionnotes develops abundantly on most of the media containing carbohydrates, but this alkaline color modification turns wine red by the addition of acids, while on rice the acid color modification develops spontaneously, turning blue by the addition of an alkali. The normal color of conidial masses is ivory yellow to brownish white, as will be seen at the upper part of the cultures of figs. 6 and 8.

PLATE 6

Fusarium moniliforme Sheldon var. *maius* Wollenweber and Reinking; pure cultures of the fungus, isolated from *Musa sapientum*, Tela, Honduras; fig. 1, on rice; fig. 2, on oatmeal agar; fig. 3, on potato tuber, showing pale orange to pale ocherous pionnotes, surrounded

by whitish mycelium, with dark violet discoloration of the plectenchymic stroma and the substratum, beginning at the top of the tuber slice; fig. 4, older stage of the same culture as in fig. 3; fig. 5, on lupine stem, showing the powdery patches of whitish mycelium that bears the *spicaria*-like chains of microconidia, with a few sporodochia scattered over the surface of the substratum and containing macroconidia, pale orange or ochreous colored, in masses. This color range agrees fairly well with that of the other species and varieties of the section *Liseola*, as well as with that of *Gibberella moniliformis*.

TEXT FIGURES

- FIG. 1. *Fusarium pusillum* Wollenweber; *a*, conidia from pionnotes of 1-month-old hard potato-agar culture; *b*, *Fusarium dimerum* Penzig; conidia and chlamydospores of 2-month-old hard potato-agar culture.
2. *Fusarium chlamydosporum* Wollenweber and Reinking; *a*, conidia from mycelium of 2-month-old hard potato-agar culture; *b*, chlamydospores in conidia and mycelium of 2-month-old hard potato-agar culture.
3. *Fusarium semitectum* Berkeley and Ravenel; *a*, conidia from mycelium of 8-day-old rice culture; *b*, conidia from mycelium of 1-month-old hard potato-agar culture; *c*, chlamydospores from 14-day-old water culture.
4. *Fusarium camptoceras* Wollenweber and Reinking; *a*, conidia, long narrow type, from mycelium of 8-day-old hard potato-agar culture; *b*, conidia, short broad type, from mycelium of 15-day-old hard potato-agar culture; *c*, chlamydospores from 15-day-old water culture; *d*, conidiophore from 12-day-old hard potato-agar culture.
5. *Fusarium incarnatum* (Robinson) Saccardo; *a*, conidia from mycelium of 1-month-old oatmeal-agar culture; *b*, conidia from mycelium of 1-month-old hard potato-agar culture; *c*, chlamydospores from 1-month-old hard potato-agar culture.
6. *Fusarium diversisporum* Sherbakoff; *a*, conidia, large, slightly curved to spindle-shaped, nonpedicellate and small, spindle-shaped, pedicellate, from mycelium of 10-day-old hard potato-agar culture; *b*, conidia, slightly curved to straight and anguiform, from pionnotes of 10-day-old oatmeal-agar culture; *c*, chlamydospores from 14-day-old water culture.
7. *Fusarium anguioides* Sherbakoff; *a*, conidia, small, narrow, slightly curved, from mycelium of 1-month-old potato-tuber plug culture; *b*, chlamydospores in conidium from 1-month-old rice culture; *c*, conidia, large and broad, nearly straight, from pionnotes of 18-day-old oatmeal-agar culture; *d*, conidia, large and broad, irregular, from pionnotes of 1-month-old rice culture.

FIG. 8. *Fusarium bullatum* Sherbakoff var. *minus* Wollenweber and Reinking; *a*, conidia from sporodochia of 14-day-old *Alnus*-stem culture; *b*, conidia from mycelium and pionnotes of 1-month-old potato-tuber plug culture.

9. *Fusarium bullatum* Sherbakoff var. *brevius* Wollenweber and Reinking; *a*, conidia from pionnotes of 8-day-old hard potato-agar culture; *b*, conidia from pionnotes of 7-day-old oatmeal-agar culture; *c*, conidia from pionnotes of 5-day-old hard potato-agar culture; *d*, conidia from pionnotes of 8-day-old *Melilotus*-stem culture.
10. *Fusarium bullatum* Sherbakoff; *a*, conidia, large, straight, non-pedicellate, from pionnotes in mycelium of 6-day-old hard potato-agar culture; *b*, conidia, smaller, pedicellate, from pionnotes and mycelium of 5-day-old hard potato-agar culture; *c*, conidia from pionnotes in mycelium of 6-day-old hard potato-agar culture; *d*, chlamydospores from 8-month-old hard potato-agar culture; *e*, conidiophore from 5-day-old hard potato-agar culture.
11. *Fusarium ossiculum* (Berkeley and Curtis) Saccardo; *a*, conidia from pionnotes of 1-month-old oatmeal-agar culture; *b*, chlamydospores, terminal and intercalary, from 1-month-old hard potato-agar culture.
12. *Fusarium falcatum* Appel and Wollenweber; *a*, conidia from sporodochia of 1-month-old *Alnus*-stem culture; *b*, conidia from pionnotes of 5-day-old hard potato-agar culture; *c*, chlamydospores from 15-day-old water culture.
13. *Fusarium acuminatum* Ellis and Everhart emend. Wollenweber; *a*, conidia from mycelium of 16-day-old oatmeal-agar culture; *b*, chlamydospores from mycelium of 2-month-old hard potato-agar culture.
14. *Fusarium caudatum* Wollenweber; *a*, conidia, long type, from sporodochia of 56-day-old rice culture; *b*, conidia from pionnotes of 15-day-old hard potato-agar culture; *c*, conidia, short type, from pionnotes of 17-day-old *Melilotus*-stem culture.
15. *Fusarium longipes* Wollenweber and Reinking; *a*, conidia, typical type, from pionnotes of 3-month-old hard potato-agar culture; *b*, conidia, short type, from pionnotes of 6-day-old hard potato-agar culture; *c*, conidia, short type, from sporodochia of 1-month-old *Alnus*-stem culture; *d*, chlamydospores from 3-month-old hard potato-agar culture and 15-day-old water culture.
16. *Fusarium anthophilum* (A. Braun) Wollenweber; *a*, conidia, long type, from pionnotes of 14-day-old oatmeal-agar culture; *b*, conidia from mycelium of 10-day-old hard potato-agar culture; *c*, conidia, short type, from pionnotes of 34-day-old rice culture; *d*, conidia and conidiophore from sporodochia of 34-day-old *Melilotus*-stem culture.

FIG. 17. *Fusarium moniliforme* Sheldon; *a*, conidia from pionnotes of one-month-old rice culture; *b*, conidia from pionnotes of 25-day-old potato-tuber plug culture; *c*, conidia from pionnotes and mycelium of 6-day-old hard potato-agar culture; *d*, conidia from sporodochia of 1-month-old *Melilotus*-stem culture; *e*, microconidia, some in chains, from mycelium of 5-day-old hard potato-agar culture; *f*, conidiophore, portion of, from mycelium of 5-day-old hard potato-agar plate culture.

18. *Fusarium moniliforme* Sheldon var. *erumpens* Wollenweber and Reinking; *a*, conidia from mycelium of 22-day-old hard potato-agar culture; *b*, early formation of sclerotial plectenchymica from mycelium in 14-day-old water culture.
19. *Fusarium moniliforme* Sheldon var. *subglutinans* Wollenweber and Reinking; *a*, conidia from pionnotes of 17-day-old hard potato-agar culture; *b*, conidia from sporodochia of 1-month-old *Melilotus*-stem culture; *c*, microconidia from mycelium of 16-day-old hard potato-agar culture; *d*, conidiophore, portion of, from mycelium of 20-day-old hard potato-agar culture.
20. *Fusarium moniliforme* Sheldon var. *maius* Wollenweber and Reinking; *a*, conidia, long, typical type, from pionnotes of 11-day-old hard potato-agar culture; *b*, conidia from sporodochia of 16-day-old *Melilotus*-stem culture; *c*, conidia from pionnotes of 11-day-old hard potato-agar culture; *d*, microconidia from pionnotes and mycelium of 11-day-old hard potato-agar culture.
21. *Fusarium neoceras* Wollenweber and Reinking; *a*, conidia from mycelium of 6-day-old hard potato-agar culture; *b*, conidia from mycelium of 20-day-old potato-tuber plug culture; *c*, macroconidia and microconidia from thin pionnotes of 37-day-old hard potato-agar culture.
22. *Fusarium fructigenum* Fries var. *maius* Wollenweber forma 1 Wollenweber and Reinking; *a*, conidia from pionnotes of 1-month-old rice culture; *b*, conidia from pionnotes of 17-day-old oatmeal-agar culture; *c*, conidia from sporodochia of 14-day-old *Melilotus*-stem culture.
23. *Fusarium decemcellulare* Brick; *a*, conidia, not typical and somewhat swollen, from pionnotes of 1-month-old green bean-pod culture; *b*, conidia, typical, from pionnotes of 4-day-old hard potato-agar culture; *c*, conidia, from sporodochia of 2-month-old hard potato-agar culture; *d*, microconidia, in chains, from mycelium of 2-month-old hard potato-agar plate culture.
24. *Fusarium macroceras* Wollenweber and Reinking; *a*, conidia, few abnormally large, from mycelium of 3-day-old oatmeal-agar culture; *b*, conidia, short and broad type, from mycelium of 2-month-old potato-tuber plug culture; *c*, conidia, typical long and slender type, from mycelium of 2-month-old hard potato-agar culture; *d*, conidia from mycelium of 19-day-old *Alnus*-stem culture.
25. *Fusarium bostrycoides* Wollenweber and Reinking; *a*, conidia from mycelium of 23-day-old hard potato-agar culture; *b*, chlamydo-

spores from mycelium of 23-day-old hard potato-agar culture; c, conidiophore, bostryxlike, from mycelium of 14-day-old *Melilotus*-stem culture, $\times 500$.

- FIG. 26. *Fusarium orthoceras* Appel and Wollenweber; a, conidia from mycelium of 15-day-old hard potato-agar culture; b, conidia from mycelium of 14-day-old oatmeal-agar culture; c, conidia from mycelium of 2-month-old potato-tuber plug culture; d, chlamydospores from mycelium of 2-month-old hard potato-agar culture.
27. *Fusarium orthoceras* Appel and Wollenweber var. *triseptatum* Wollenweber; a, conidia from mycelium of 16-day-old hard potato-agar culture; b, conidia from mycelium of 11-day-old hard potato-agar culture; c, chlamydospores from 32-day-old hard potato-agar culture; d, chlamydospores from 16-day-old hard potato-agar culture.
28. *Fusarium bulbigenum* Cooke and Massee; a, conidia from mycelium and pionnotes of 16-day-old oatmeal-agar culture; b, conidia from minute sporodochia of 14-day-old *Alnus*-stem culture; c, chlamydospores from mycelium of 15-day-old oatmeal-agar culture and from minute sporodochia of 14-day-old *Alnus*-stem culture.
29. *Fusarium oxysporum* Schlechtendal emend. Wollenweber; a, conidia from pionnotes of 2-month-old rice culture; b, conidia from pionnotes of 25-day-old hard potato-agar culture; c, conidia from pionnotes of 25-day-old hard potato-agar culture; d, conidia, short type, from sporodochia of 17-day-old *Melilotus*-stem culture; e, conidia from pionnotes of 23-day-old hard potato-agar culture; f, chlamydospores from 3-month-old green bean-pod culture.
30. *Fusarium oxysporum* Schlechtendal var. *nicotianae* Johnson; a, conidia, long and short types, from pionnotes of 28-day-old potato-agar culture; b, conidia from pionnotes of 22-day-old rice culture; c, conidia from pionnotes of 22-day-old *Melilotus*-stem culture; d, conidia from pionnotes of 22-day-old *Melilotus*-stem culture; e, chlamydospores from 22-day-old *Melilotus*-stem culture and 2-month-old hard potato-agar culture; f, conidiophore, portion, from pionnotes of 3-month-old hard potato-agar culture.
31. *Fusarium cubense* Erwin F. Smith; a, conidia, long, rarer type, from pionnotes of 16-day-old hard potato-agar culture; b, conidia, typical, shorter type, from sporodochia of 14-day-old *Melilotus*-stem culture; c, conidia, typical, from pionnotes of 22-day old *Melilotus*-stem culture; d, conidia, typical, from sporodochia of 2-month-old hard potato-agar culture; e, chlamydospores from conidia and mycelium of 22-day-old hard potato-agar culture; f, conidiophore, portion, from pionnotes of 19-day-old banana-peel culture.
32. *Fusarium aurantiacum* (Link) Saccardo emend. Wollenweber; a, conidia from sporodochia of 26-day-old potato-tuber plug culture; b, conidia from sporodochia and mycelium of 12-day-old hard potato-agar culture; c, chlamydospores from mycelium of 1-month-old hard potato-agar culture.

FIG. 33. *Fusarium lutulatum* Sherbakoff; *a*, conidia from pionnotes of 5-day-old hard potato-agar culture; *b*, conidia from pionnotes of 3-month-old hard potato-agar culture; *c*, chlamydospores from 3-month-old hard potato-agar culture.

34. *Fusarium solani* (Martius p. p.) Appel and Wollenweber var. *minus* Wollenweber; *a*, conidia from pionnotes of 25-day-old hard potato-agar culture; *b*, conidia from pionnotes of 15-day-old oatmeal-agar culture; *c*, conidia and chlamydospore from pionnotes of 16-day-old hard potato-agar culture.
35. *Fusarium solani* (Martius p. p.) Appel and Wollenweber var. *suffusum* Sherbakoff; *a*, conidia from mycelium of 2-month-old hard potato-agar culture; *b*, conidia from mycelium of 1-month-old *Melilotus*-stem culture; *c*, chlamydospores from 2-month-old hard potato-agar culture; *d*, conidiophore from mycelium of 1-month-old green bean-pod culture.
36. *Fusarium solani* (Martius p. p.) Appel and Wollenweber; *a*, conidia from pionnotes of 24-day-old hard potato-agar culture; *b*, conidia from pionnotes of 3-month-old hard potato-agar culture.
37. *Fusarium alluviale* Wollenweber and Reinking; *a*, conidia from pionnotes of 25-day-old hard potato-agar culture; *b*, conidia from sporodochia of 21-day-old *Melilotus*-stem culture; *c*, conidium from pionnotes.
38. *Fusarium martii* Appel and Wollenweber var. *minus* Sherbakoff; *a*, conidia from pionnotes of 22-day-old hard potato-agar culture; *b*, conidia from pionnotes of 3-month-old hard potato-agar culture; *c*, chlamydospores from 3-month-old hard potato-agar culture; *d*, conidiophore from sporodochia of 11-day-old green bean-pod culture.
39. *Fusarium martii* Appel and Wollenweber var. *viride* Sherbakoff; *a*, conidia from pionnotes of 7-day-old hard potato-agar culture; *b*, conidia from pionnotes of 7-day-old hard potato-agar culture; *c*, chlamydospores from 21-day-old hard potato-agar culture.
40. *Fusarium martii* Appel and Wollenweber; *a*, conidia, typical, from pionnotes of 9-day-old potato-tuber plug culture; *b*, conidia, small type, from pionnotes of 23-day-old hard potato-agar culture; *c*, conidiophore from 8-day-old green bean-pod culture.
41. *Fusarium viride* (Lechm.) Wollenweber; *a*, conidia from pionnotes of 3-month-old hard potato-agar culture; *b*, conidium from sporodochia of 21-day-old *Melilotus*-stem culture; *c*, conidia from pionnotes of 15-day-old potato-tuber plug culture; *d*, chlamydospores in conidium from 3-month-old hard potato-agar culture.
42. *Fusarium radicicola* Wollenweber; *a*, conidia from pionnotes of 15-day-old rice culture; *b*, conidia and chlamydospores from pionnotes of 3-month-old hard potato-agar culture.
43. *Fusarium striatum* Sherbakoff; *a*, conidia from pionnotes of 18-day-old potato-tuber plug culture; *b*, conidia from pionnotes of 16-day-old oatmeal-agar culture; *c*, chlamydospores from 14-day-old potato-tuber plug culture; *d*, conidiophore from mycelium of 23-day-old green bean-pod culture.

- FIG. 44. *Fusarium javanicum* Koorders; *a*, conidia from pionnotes of 24-day-old hard potato-agar culture; *b*, conidia from pionnotes of 17-day-old rice culture; *c*, conidia from sporodochia of 18-day-old *Melilotus*-stem culture; *d*, chlamydospores from 16-day-old hard potato-agar culture.
45. *Fusarium theobromae* Appel and Strunk; *a*, conidia from mycelium of 1-month-old oatmeal-agar culture; *b*, conidia from mycelium of 15-day-old hard potato-agar culture; *c*, chlamydospores from 1-month-old hard potato-agar culture.
46. *Fusarium ensiforme* Wollenweber and Reinking; *a*, conidia from sporodochia of 14-day-old *Alnus*-stem culture; *b*, chlamydospores from 14-day-old water culture.
47. *Hypomyces ipomoeae* (Halsted) Wollenweber; *a*, conidia from mycelium of 18-day-old potato-tuber plug culture; *b*, conidia from mycelium of 9-day-old hard potato-agar culture; *c*, perithecium, $\times 100$, from 20-day-old hard potato-agar culture; *d*, chlamydospores from 2-month-old hard potato-agar culture; *e*, ascus and ascospores from 10-day-old hard potato agar culture.



PLATE 1.



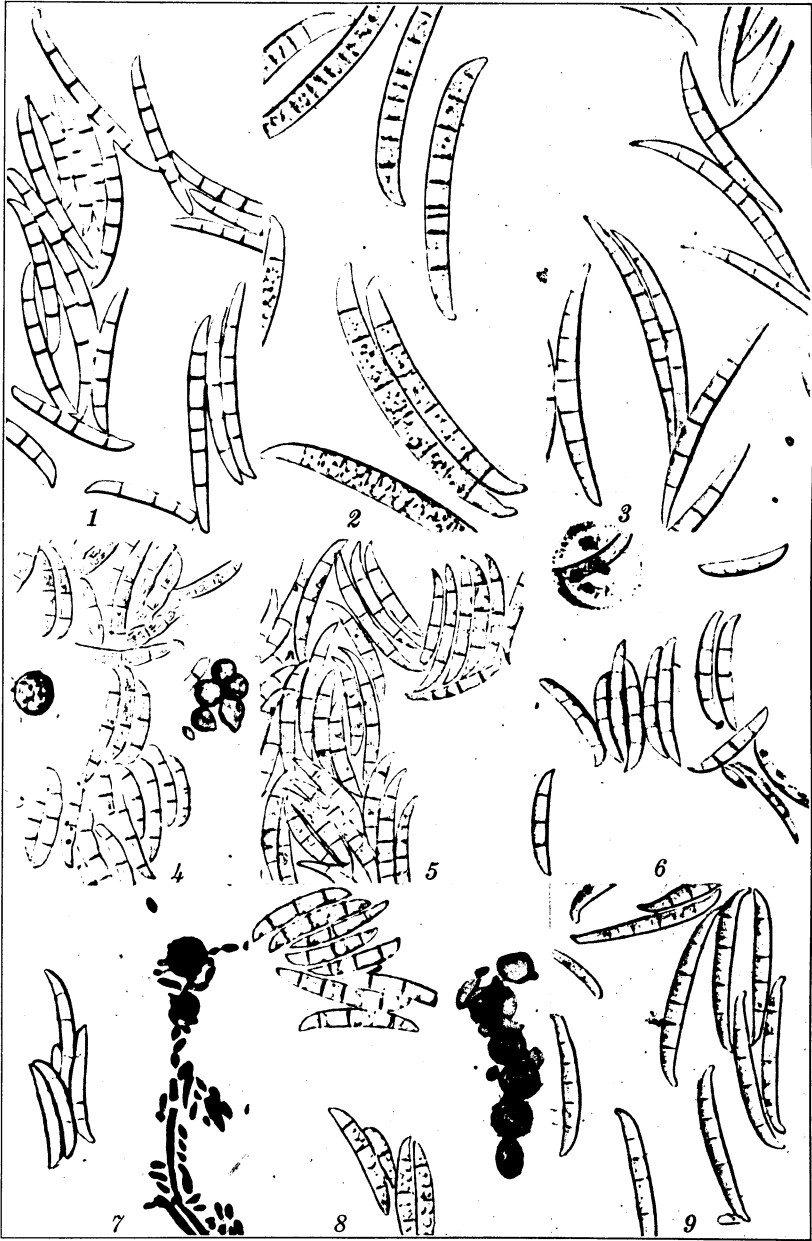


PLATE 2.





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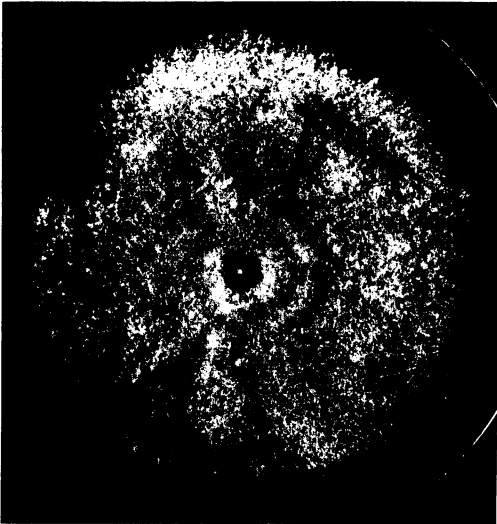


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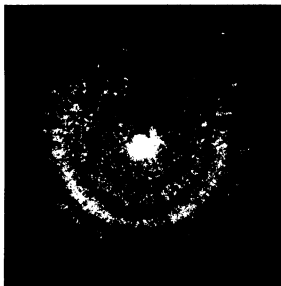




1



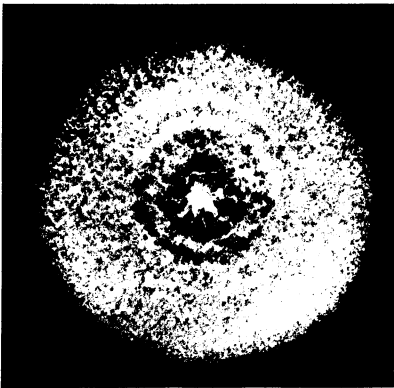
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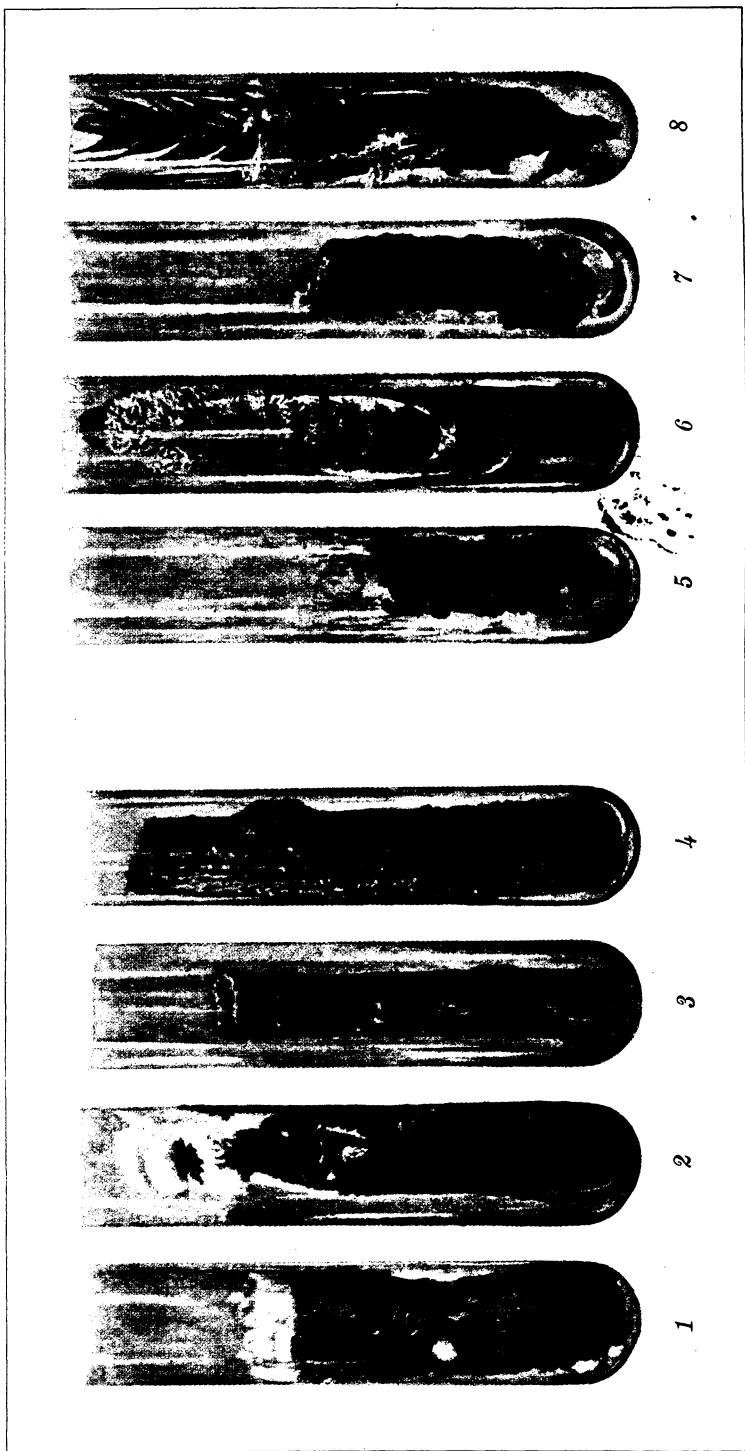


PLATE 5.



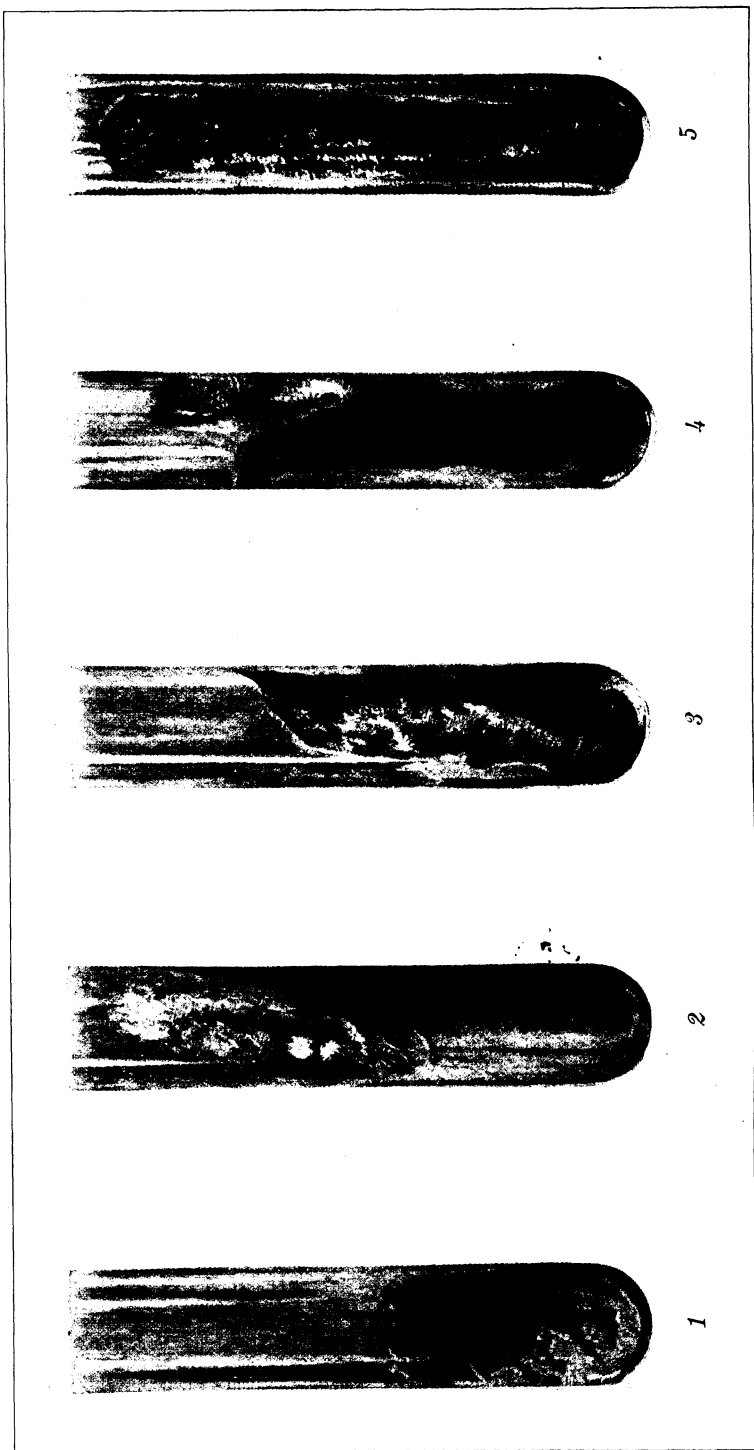


PLATE 6.



THE CALAMBAYUNGAN AND LARAP IRON-ORE DEPOSITS OF MAMBULAO, CAMARINES NORTE PROVINCE, PHILIPPINE ISLANDS

By F. R. TEGENGREN

Formerly of the China Geological Survey, Peking, China

FOUR PLATES AND TWO TEXT FIGURES

INTRODUCTION

The Calambayungan * deposits were described by W. E. Pratt.¹ At that time, however, no exploratory work whatever had been undertaken, and little was known about the size of the ore bodies occurring there. Their existence was merely indicated by the more or less frequent occurrence of ore boulders in the surface soil, as well as by a few natural outcrops, affording little clew to the shape and persistence of the deposit. Under these circumstances it may be of interest to present here a more comprehensive account, based on the data obtained in the course of the extensive exploration work conducted by the present writer in 1923 for a large mining concern.

SITUATION AND TOPOGRAPHY

The deposits are situated in the southern part of Luzon, on the east coast of the island, about 5 kilometers (3 miles) west of the town of Mambulao, from which they are separated by Mambulao Bay. The locality lies 185 kilometers (115 miles) in a straight line about east by south of Manila. Mambulao, which is a town of about 2,000 inhabitants, has weekly communication with Manila by the through express train between this place and Hondagua, a port at Lopez Bay on the east coast, about 65 kilometers (36 miles) southwest of Mambulao. From Hondagua a steamer, connecting with the express train, runs once a week along the coast eastward, one of its ports of

* This name is spelled Calambayanga in the Census of the Philippine Islands and on Coast and Geodetic Survey charts. People living in the vicinity of the island call it Calambayungan.—EDITORS.

¹ Philip. Journ. Sci. § A 10 (1915) 323-331.

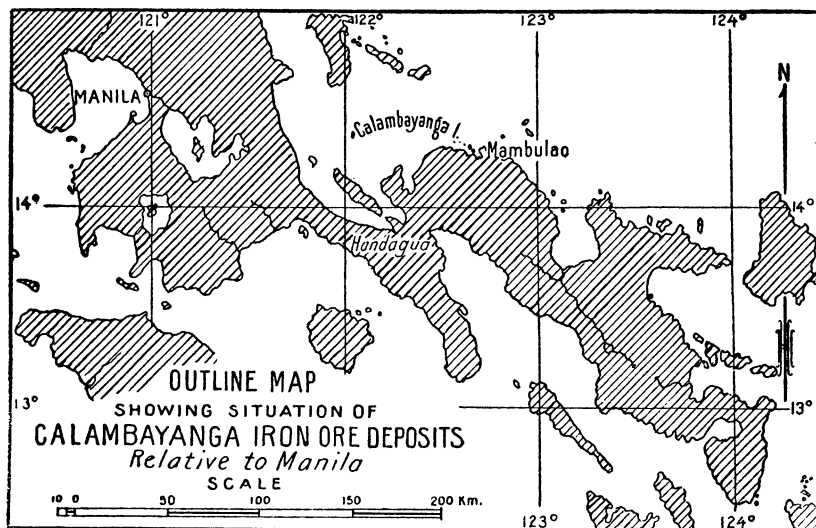


FIG. 1. Southern Luzon, showing the location of the Mambulao region.

call being Mambulao. The whole trip can be made in less than twenty-four hours. By the sailing route around southeastern Luzon the distance from Manila to Mambulao is about 900 kilometers (500 miles).

The deposits occupy parts of Larap Peninsula and Calambayungan Island; the latter is separated from the former by a shallow channel, about 40 meters (1,300 feet) broad. Off the northwest point of the island the sea has a depth of 5 to 7 fathoms (10 to 13 meters) within a distance from the shore of less than 200 meters (600 feet), and a pier could be easily constructed to this deep-water edge. On the other hand, the coast is rather open, but a breakwater, comparatively inexpensive, would provide sufficient protection, except during occasional typhoons, when loading vessels would have to run for shelter to the nearest typhoon harbors. For small vessels Dahan Bay, a few kilometers west of Calambayungan Island, is a sufficiently safe harbor, while larger vessels would have to take refuge in a bay about 80 kilometers east of Mambulao. Under the present system of notification a vessel can always be advised of dangerous weather twenty-four hours ahead, providing ample time for precautions.

Most of the rainfall occurs from October to March, inclusive, when the northeast monsoon from the sea carries abundant humidity, while the months of April to September, when calm weather and winds from other directions prevail, are compar-

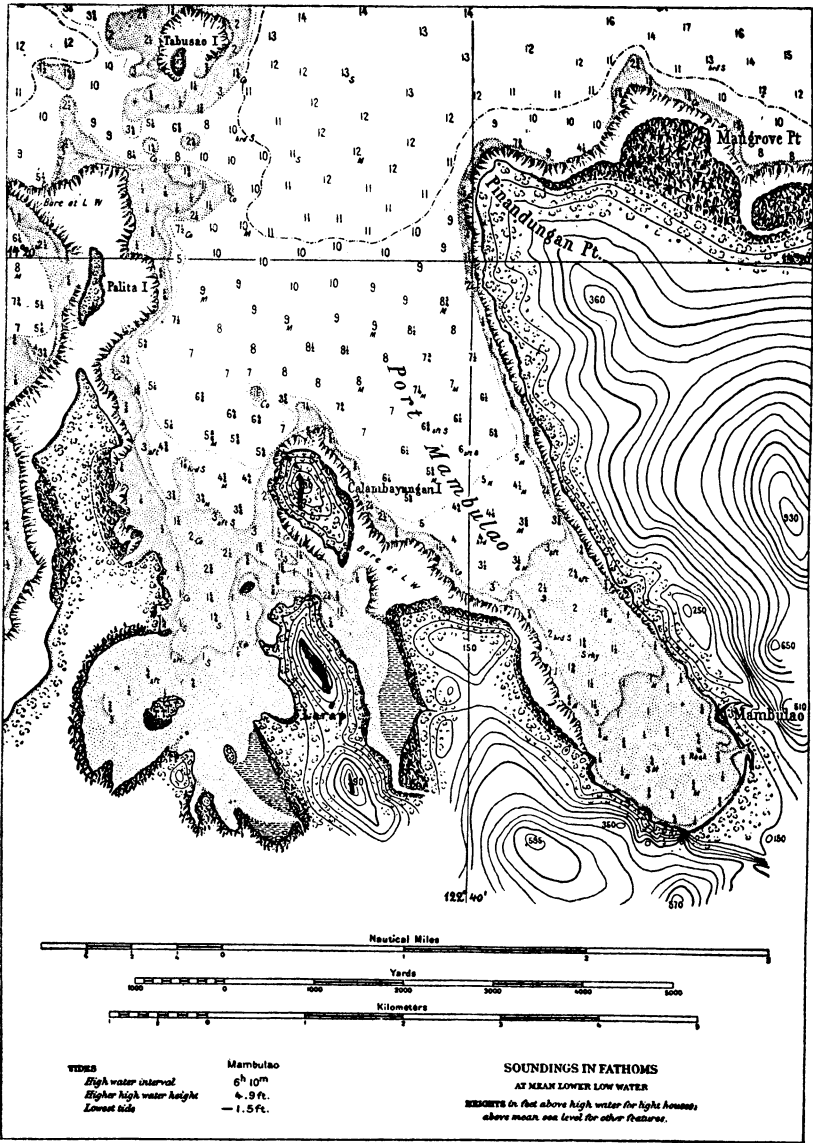


FIG. 2. The Mambulao region.

atively dry. Hence the latter season would offer favorable conditions for shipping. Table 1 has been compiled from the weather reports regarding Legaspi, which is the observation station nearest to Mambulao.

TABLE 1.—*Showing wind percentages for one year at Legaspi.*

Wind from—	Percentage, June to October.	Percentage, November to May.	Percentage for entire year.
(*)	29	14	20
North	6	24	16
Northeast	15	47	34
East	6	11	9
Southeast	1	0	1
South	6	1	2
Southwest	27	2	13
West	9	1	4
Northwest	1	0	1
	100	100	100

* Calm.

From Table 1 it will be seen that it is calm during 20 per cent of the year, while the wind blows from the north or northwest (the only unprotected directions) for 17 per cent of the time. The other 63 per cent of the time the wind blows from directions against which there is shelter. This would seem to indicate 83 per cent of "working weather" during the year. In a similar way it may be figured out that there should be 93 per cent of "working weather" during the five-month period, June to October (inclusive), while during the rest of the year there should be about 76 per cent of "working weather."²

The whole region is heavily forested. Only small patches along the shores have been cleared to give place to coco groves or banana and abacá plantations, and hence the district can be traversed only along certain trails cut through the tropical jungle of shrubbery and dense cordlike creepers. Trees of valuable hardwood, many of them of large size, grow abundantly and would yield an ample supply of timber for railroad sleepers, trestles, piers, etc. On the other hand, the clearing off of the iron-ore hills, previous to exploitation of the deposits, would not offer any great difficulties, as the undergrowth could be easily burned during the dry season.

² These data regarding weather conditions have been compiled and kindly communicated by Judge Frank B. Ingersoll.

Camarines Norte Province occupies the northernmost part of the Southeastern Cordillera. Hence the region is hilly, with altitudes up to 1,000 meters (3,280 feet).

Larap Peninsula consists of a hill ridge, extending north and south for a distance of about 2.5 kilometers (more than 8,200 feet) with a maximum elevation of about 100 meters (330 feet) in its southern portion and gradually lowering toward the north. Its eastern flank dips rather steeply into the bay, while on the western side there is a flat-lying strip of land between the shore and the base of the ridge. In the shallow water along the beach there is a more or less continuous fringe of mangrove swamps.

The channel between the point of the peninsula and Calambayungan Island—which may be said to form a continuation of the Larap ridge—is shallow, at most 1.5 fathoms (2.7 meters) deep. The bottom consists of a hard and rather even coral reef, on which a railway trestle could easily be laid to connect the peninsula with the deep water off the northwestern shore of the island. The ridge on the island traverses its northwestern portion, where the summit has an elevation of about 65 meters (210 feet) above the sea level, while the southeastern portion is lower and partly level, thus offering a suitable site for a mining town. The local fresh-water supply on the island would probably be insufficient for a large settlement, but on the eastern shore of Mambulao Bay there are several creeks of adequate size from which the water could be conveyed by pipe lines across the bay.

HISTORICAL NOTES

Pieces of iron slag found near Mambulao indicate the existence during some period in the past of a primitive iron industry, utilizing the ore of Calambayungan or Larap. Neither local tradition nor official documents seem to give any accurate information regarding this extinct iron-smelting industry. It is only recorded that during the Spanish control of the Philippines concessions for iron mines on Calambayungan Island were repeatedly sought. On the other hand, it is known that the iron ores farther north in the Luzon cordillera were exploited in the seventeenth and eighteenth centuries. Probably the Mambulao deposits were discovered at a similarly early date, since gold mining is known to have been carried on for three centuries in this region.

In modern times the Mambulao deposits attracted the interest of A. C. Cavender, a mining engineer who had been for many years engaged in gold mining in the same district. Later Mr. Joaquin Casanovas became associated with him.

In 1918 Cavender and Casanovas leased their holdings on Calambayungan Island to a Japanese company, which planned to ship ore to Japan for smelting in blast furnaces in that country.

A wooden pier, about 100 meters long, was built from the beach toward the deep water's edge and a narrow-gauge railroad track was laid down southward along the base of the western slope. Ordinary bench-quarrying methods were used, but most of the output was obtained from boulders and rubble occurring in the superficial clay.³ The ore was delivered by means of wooden chutes to the lower benches on the railroad, where it was loaded into hand cars to be dumped into scows at the pier. The company is stated to have employed 300 to 500 men and the daily output at times reached 100 to 150 tons. However, in 1919 the mining operations were suspended, owing to the cessation of the war boom; the Japanese engineers and "bosses" left the place, and the mining property was restored to its owners. The total shipment of iron ore is stated to have been 48,000 tons. As already mentioned, most of this ore was derived from surface boulders and no systematic prospecting and development was done by the Japanese leaseholders.

EXPLORATORY WORK

On Larap Peninsula the deposits of iron ore are found within the boundaries of four patented mining claims known as the Busser, Superior, Bessemer, and Rescue claims, which have a combined area of 192 hectares.

On Calambayungan Island the deposits are confined to the northern half of the island, an area of about 35 hectares.

A large mining concern that was investigating the Mambulao deposits did a considerable amount of exploratory trenching work, both on Larap Peninsula and on Calambayungan Island, in 1923. The organization and superintendence of this work was entrusted to Mr. E. A. Heise, an American who, for eighteen years, had traveled extensively in the Islands, engaged in gold prospecting, dredging, and mining, and who thus possessed a very thorough and valuable experience in such work.

³ Min. Resources P. I. for 1917-1918 (1920) 25.

Thanks to his energetic efforts the work, which was begun about the first of March, proceeded rapidly, effectively, and smoothly and was brought to a conclusion in the middle of August.

The workers were selected exclusively from among the local inhabitants, and the number varied from fifty to one hundred. The population of Mambulao, having previously subsisted mainly on the gold-mining industry, had been hard hit by the cessation of this industry a few years before and the men were eager to avail themselves of this opportunity for temporary employment. In Mr. Heise's opinion, it would not have been difficult to get at least two hundred good laborers from among the local population; and, by drawing on the available labor in the surrounding districts, a supply in excess of the requisite number for exploiting the ore deposits on a commercial scale could probably be secured.

The efficiency of the picked men employed for the exploratory work seemed to be quite satisfactory; indeed, they worked hard from 5 a. m. until 5 p. m. with scarcely an hour's intermission for the midday meal. As shown by the subjoined tables, a considerable amount of work was performed. However, as already intimated, these men were picked, and an increase in the number to several hundred would most likely entail a lowering of the standard.

The scale of wages for all kinds of labor in the Philippine Islands is comparatively high, for ordinary labor roughly three times as high as in China, one peso being the usual daily wage. This was also the price paid to the workmen employed for the exploratory work.

The trenches were dug, with an interval of about 100 meters (330 feet), at right angles to the trend of the ridge and with an average width of from 1.2 to 1.3 meters (4 to 4.5 feet). From the bottom of these trenches square vertical test pits were sunk, at certain intervals, as deep as possible. The soft surface clay and the almost equally soft, decomposed country rocks could be excavated by pick and shovel only, while most of the ore had to be blasted by dynamite. The walls of the trenches and pits, on the whole, stand well. That, nevertheless, considerable trouble was experienced from caving in was due to the abnormal amount of rainfall during what should have been the dry season.

Altogether twenty-two trenches were cut across the Larap ridge; in addition five minor stray trenches were dug, four of

which were intended to serve as assessment work on the original claims Nos. 5 and 6. The fifth trench is a small one, located on the eastern flank of the ridge, between the Busser and the Superior claims. The aggregate length of the Larap trenches amounts to about 1,500 meters (5,000 feet), and the average depth to about 1.8 meters (6 feet). As mentioned above, the width is roughly 1.2 meters. Hence the total volume of these excavations amounts to about 3,400 cubic meters or, say, 116,000 cubic feet. From the bottom of the trenches one hundred eight pits were sunk, with an average depth of 3.7 meters (maximum 7.5 meters) and a total volume of more than 600 cubic meters or, say, 22,000 cubic feet.

On the island, nine trenches were cut, with an aggregate length of 585 meters (1,920 feet), an average depth of 1.7 meters (6 feet), and a volume of 1,300 cubic meters (46,000 cubic feet). There are fifty-nine pits, with an average depth of 3.1 meters (10 feet) and a total volume of 270 cubic meters (9,500 cubic feet).

The details for each trench are given in Table 2 which should be confronted with the vertical sections on Plate 2.

GEOLOGY AND ORE DEPOSITS

According to the geologists of the Philippine Bureau of Science⁴ the Eastern Cordillera is a complex of pre-Tertiary igneous rocks on which has been deposited a younger sedimentary series. The whole complex has been tilted, largely metamorphosed, and intruded by dikes of basic composition (diorite, diabase, gabbro, partly with porphyritic texture) and overspread by flows of agglomerates (andesite). The upper beds are tuffs, clays, and sands of Pleistocene to Recent age, while the lower part of the series is made up of shales, sandstones, arkoses, and limestones, assigned to the Miocene and Oligocene.

The iron ore is found at the base of the sedimentaries, near their contact with the underlying igneous basement. At Larap and Calambayungan the sedimentary rocks consist of sandstones, conglomerates, shales, tuffs, and minor limestone intercalations. The whole series has a general trend north and

⁴ See W. E. Pratt, *Philip. Journ. Sci.* § A 10 (1915) 323-331; and *Min. Resources P. I.* for 1913 (1914) 21-31. Also W. D. Smith, *Philip. Journ. Sci.* § A 8 (1913) 235; and *Min. Resources P. I.* for 1909 (1910) 33.

south, with local variations up to north 40° west, and dips uniformly westward at varying angles. Near the ore deposit, the rocks—both igneous and sedimentary—have been thoroughly decomposed, largely forming a soft, clayey mass, the original nature of which cannot be determined.

TABLE 2.—*Showing details of trenches.*

LARAP PENINSULA.

Designation.	Trench.			Pits.		
	Length.	Average depth.	Volume.	Number.	Average depth.	Volume.
	m.	m.	cu. m.		m.	cu. m.
H ¹	40	1.6	73	0	0	0
G ¹	50+43	1.0	120	0	0	0
F ¹	130	1.7	220	4	2.5	15
E ¹	114	1.6	236	2	2.0	6
1.....	32+60	1.8	214	6	3.0	27
2.....	104	2.0	270	10	3.9	58
3.....	31+36	1.6	139	6	3.0	27
4.....	47	1.5	91	5	3.0	23
5.....	30+19	1.9	121	8	3.0	36
6.....	90	1.9	222	8	2.8	34
7.....	118	2.1	321	10	5.0	75
8.....	113	1.9	278	12	5.0	90
9.....	39	1.5	75	4	3.5	21
10.....	52	2.0	135	6	3.5	31
11.....	46	2.0	119	3	4.3	19
12.....	39	2.0	101	3	4.8	22
13.....	42	2.2	119	3	3.8	17
14.....	18+24	1.7	92	5	5.0	38
15.....	61	2.0	158	7	5.3	56
16.....	39	2.4	93	5	4.4	33
17.....	44	2.2	124	0	0	0
18.....	30	2.0	75	1	7.0	9
Total and average.....	1,491	1.8	3,396	108	3.7	637

CALAMBAYUNGAN ISLAND.

A.....	40	2.0	104	6	3.5	32
B.....	48	1.5	93	5	3.4	25
D.....	58	1.5	113	8	3.5	42
E.....	28	1.7	61	3	2.3	10
F.....	105	1.8	245	10	2.2	33
G.....	72	2.2	295	9	3.3	44
H.....	49	1.8	114	6	4.2	38
I.....	118	1.7	260	6	3.0	27
K.....	67	1.4	120	6	2.3	21
Total and average.....	585	1.7	1,315	59	3.1	272

* The depth of the pits has been reckoned from the bottom of the trenches, not from the surface.

The ore-bearing strata extend from the northwestern point of Calambayungan Island toward the south and southwest, across the highest portion of the island, to the vicinity of its southwestern shore. Across the gulf between the island and the northern point of Larap Peninsula there is an interruption of about 0.8 kilometer (2,600 feet) after which the ore zone can be traced southward along the central ridge, to the southern end of the peninsula. The total distance from the northwestern point of the island to the southern termination of the iron-bearing zone is about 3.5 kilometers (2.2 miles).

Of this total extent of the iron-bearing formation, about 750 meters (2,460 feet) belong to the island, while on the peninsula the ore bodies cover a length of about 2,150 meters (7,050 feet). Outside of this main iron-bearing belt, there is, on the western side, a minor area cropping out on an islet.

Again, at Batobolani, about 10 kilometers (6 miles) southeast of Larap and also near the line of contact between the sedimentaries and the older igneous rocks, there is a similar outcrop.

Due to the fact that the iron ore is harder, much less decomposed, and much less easily eroded than the associated rocks, its outcrops stand out in prominent relief so that the iron-ore belt forms the backbone of the whole ridge. This is a great advantage from the mining point of view, rendering the ore bodies much more easily accessible.

As is illustrated by the map, the ore does not occur as a continuous layer along the whole extent of the iron-bearing belt but forms detached bodies, separated by barren intervals. The shape of these bodies is irregularly tabular or lenticular; sometimes they swell out to a considerable width, sometimes they taper abruptly and pinch out. This peculiarity seems not only to apply to their extent on the surface; the same feature also appears on the cross sections. The latter show, moreover, that the dip is gently to the west, its angle in a general way conforming with the dip of the encasing sedimentary strata. Since this angle is, as a rule, slightly larger than the grade of the western flank of the ridge, it follows that the amount of overburden will probably increase somewhat toward the base of the ridge.

From the mode of occurrence indicated above it may be reasonably presumed that the extent of the ore bodies along the dip is roughly equidimensional with their horizontal length, and that the irregularities shown by the plan and the sections will

be repeated in a similar way in the deeper portions of the ore bodies not yet exposed.

In addition to this solid ore in place, there is a not inconsiderable amount of ore occurring as subangular boulders and pebbles scattered over the surface and embedded in the residual surface clay on the flanks of the ridge and along the beach. Certain areas, marked approximately on the map, are littered with such ore boulders and their abundance may, at first sight, induce one to believe that solid ore is to be found in place underneath. As amply proved by the trenching work performed, however, this is not the case. On closer inspection, it appears that they are surficial accumulations of exactly the same kind as those connected with the iron-ore deposits in the lower Yangtse Valley in China.⁵ These boulder accumulations are evidently the result of an intense differential weathering and erosion, leaving the hard and heavy ore comparatively intact, and preferably removing the encasing soft and light sedimentaries. In their present position the boulder accumulations seem to be derived partly from the big outcrops on the crest of the ridge, wherefrom they have been detached and have gradually slidden downward during the process of erosion and waste-creep; partly they seem to be remnants of minor nests, originally inclosed in the sedimentaries near the spot where they are now found.

CHARACTER OF THE ORE

The iron ore of the Larap and Calambayungan deposits consists of nearly pure hematite, with a very subordinate intermixture of gangue matter. The hematite is partly hard and crystalline, partly soft and rather friable. It is rather dense-grained but at the same time porous and vesicular. Quartz is the commonest and most uniformly distributed gangue matter; it seems to fill the interstices between the hematite individuals, and it also forms druses lining small vugs and veinlets in the ore mass. Occasionally even rock crystals of considerable size (70 centimeters in length) have been found. On an average, however, the percentage of quartz hardly exceeds 3 per cent. Pyrite, in the shape of small specks and lumps, is occasionally though sparsely encountered. Green copper stains, resulting from the weathering of such pyrite, indicate that the latter is somewhat cupriferous. Frequently there are specks of a whit-

⁵ See the present writer's work, *Iron Ores and Iron Industry of China*, *Memoirs Geol. Survey of China*, Ser. A. (1921-1924) No. 2.

ish, clayey substance in the ore. In the rich ore this substance occurs only very sparsely, but in the somewhat poorer grades which form the transition between the ore body and the encasing clay-shale, this substance forms streaks and fragments of considerable size. The ore is very low in phosphorus, and this element seldom exceeds the Bessemer limit.

Surfaces of the ore long exposed to rain and wind exhibit a peculiar polished, but at the same time irregularly pitted, appearance, evidently due to the leaching out of softer portions of the ore.

A number of samples collected under my supervision have been assayed in the laboratory of the Kailan Mining Administration at Tongshan, China. The results are given in Table 3.

GENESIS OF THE ORE

In general character and habit the ore in these deposits strikingly resembles the ores of the Yangtse Valley, already referred to, which are beyond doubt of contact-metamorphic and metasomatic origin. The likeness also extends to many features relating to the shape and mode of occurrence of the deposits. These facts strongly suggest a similar origin for the Mambulao deposits, although the scarcity of outcrops prohibits a closer study of the relationships between the ore and the as-

TABLE 3.—*Showing assay of ore samples from Calambayungan and from Larap Peninsula.*

CALAMBAYUNGAN ISLAND.

Sample from—	Insoluble in hydro- chloric acid (HCl).	Silicon oxide (SiO ₂).	Iron (Fe).
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Trench A, bottom and walls of trench.....	3.00	2.45	63.75
Trench A, pits.....	6.60	6.45	60.74
Trench B, bottom and walls of trench.....	2.10	1.90	64.92
Trench B, pits.....			
Trench D, bottom and walls of trench.....	2.90	2.70	64.64
Trench D, pits.....	9.10	8.50	60.79
Trench F, bottom and walls of trench.....	2.45	2.25	65.43
Trench F, pits.....	4.50	4.10	64.15
Trench G, bottom and walls of trench.....	2.05	1.75	63.87
Trench G, pits.....	5.10	4.00	62.19
Trench H, bottom and walls of trench.....	1.45	1.30	65.10
Trench H, pits.....	2.00	1.50	64.32
Trench I, bottom and walls of trench.....	2.25	2.00	64.99
Trench K, pits.....	1.40	1.20	66.32
Average.....	3.45	3.08	63.94

TABLE 3.—Showing assay of ore samples from Calambayungan and from Larap Peninsula—Continued.

LARAP PENINSULA.

Main ore body:			
Trench 1, bottom and walls of trench.....	11.27	8.10	53.77
Trench 1, pits.....	3.20	2.85	63.60
Trench 2, bottom and walls of trench.....	3.57	3.35	63.40
Trench 2, pits.....	6.60	5.95	59.00
Trench 3, bottom and walls of trench.....	2.40	2.21	64.41
Trench 3, pits.....	8.77	3.20	63.00
Trench 4, bottom and walls of trench.....	4.75	4.35	62.39
Trench 4, pits.....	4.27	3.60	63.54
Trench 5, bottom and walls of trench.....	5.62	4.97	61.44
Trench 5, pits.....	3.45	2.80	62.10
Trench 6, bottom and walls of trench.....	1.20	1.10	64.80
Trench 6, pits.....	1.65	1.40	63.60
Trench 7, bottom and walls of trench.....	1.00	0.90	66.54
Trench 7, pits.....	1.00	0.90	64.65
Trench 8, bottom and walls of trench.....	3.05	2.75	62.06
Trench 8, pits.....	4.25	3.75	59.53
Trench 9, bottom and walls of trench.....	3.12	2.81	62.35
Trench 9, pits.....	2.70	2.40	64.15
Average.....	3.70	3.19	62.45
Minor ore bodies:			
Trench 10, bottom and walls of trench.....	7.77	6.82	55.34
Trench 10, pits.....	7.30	5.45	60.11
Trench 13, bottom and walls of trench.....	2.22	1.99	64.83
Trench 13, pits.....	3.25	2.50	63.48
Trench 15, bottom and walls of trench.....	5.32	4.10	60.62
Trench 15, pits.....	7.15	6.20	59.94
Trenches 17 and 18, bottom and walls of trench.....	14.25	11.75	55.39
Trench 17, pits.....	8.20	6.75	59.11
Average.....	6.93	5.69	59.84

sociated rocks. That the seemingly massive ore has originated by replacement of a preëxisting bedded rock is seen in some outcrops, where the weathering has revealed, and partly sculptured out, the bedding structure of the original rock. The source of the iron-bearing solutions, that dissolved and substituted certain, probably calcareous, strata in the sedimentary series, cannot be determined with certainty; but Pratt's supposition, that this mineralization was effected by later emanations from the same igneous source as that from which the volcanic dike rocks are derived, seems plausible. The gold-bearing quartz veins are also related to the same dike rocks.

ESTIMATE OF ORE RESOURCES

We may exclude from this estimate the two minor ore bodies in the southern part of Larap Peninsula, because of their re-

mote situation and somewhat inferior quality. Hence we only figure on the main ore body, extending between trenches 1 and 9. This ore body is approximately 700 meters long, while along the dip, westward and downward, it may reasonably be expected to extend to the base of the hill, a distance of 250 to 300 meters on the average. However, only the upper portion may be considered as ore in sight. Therefore, it seems advisable to include in the calculation only the upper 100 meters, although, no doubt, there are additional resources in the lower portion of the western flank.

TABLE 4.—*Complete analyses of mixtures of all the samples in equal proportions.*

	Larap Peninsula.	Calamba-yungan Peninsula.
	<i>Per cent.</i>	<i>Per cent.</i>
Loss by calcination.....	3.59	3.02
Silicon dioxide (SiO ₂).....	3.51	2.97
Aluminium oxide (Al ₂ O ₃).....	3.58	2.80
Titanium oxide (TiO ₂).....	None	None
Ferric oxide (Fe ₂ O ₃).....	87.34	89.51
Ferrous oxide (FeO).....	1.53	1.60
Manganese oxide (MnO ₂).....	0.20	0.22
Calcium oxide (CaO).....	0.19	0.26
Magnesium oxide (MgO).....	Traces	Traces
Barium oxide (BaO).....	0.065	0.014
Phosphorus pentoxide (P ₂ O ₅).....	0.20	0.09
Sulphur trioxide (SO ₃).....	0.22	0.44
Total.....	100.425	100.924
Metallic iron (Fe).....	62.30	63.88
Phosphorus (P).....	0.09	0.04
Sulphur (S).....	0.09	0.18

Turning to the island, it is to be noted that out of the total length of the iron-bearing formations—750 meters—only about 480 meters, or roughly 60 per cent, actually contain ore, while the remaining 270 meters are barren, at least as far as the test pits and trenches reach. In computing the amount of ore it may reasonably be assumed that the same proportion between ore bodies and barren intervals also obtains in the direction of the dip. It is also to be expected that the extension in the latter direction of the ore formation as a whole, including ore bodies and barren intervals, will be roughly equidimensional with the horizontal extent, and that hence it is fairly safe to assume that the ore formation will continue undiminished as

far as the base of the hill at the western shore of the island. This distance, from the crest of the ridge to the western shore, is only about 170 meters on the average. Since, however, the lower portion of this strip of the ore formation may be buried underneath too thick an overburden of rocks and soil to be easily workable, only the uppermost 100 meters will here be taken into account.

The average thickness of the ore, as measured on the sections, is given in Table 5.

TABLE 5.—Average thickness of iron-ore bodies.

Section.	Larap Peninsula.	Meters.
1		7.0
2		8.5
3		7.0
4		10.0(?)
5		18.0
6		6.0
7		5.0
8		5.0
9		4.5
Average		7.3
	Calambayungan Island.	
A		5.0
D		5.5
F		4.0
G		5.0
H		7.0
I		3.5
K		3.5
Average		4.8

Applying the principles and data set forth in the foregoing, the easily available resources can be computed as shown in Table 6, the specific gravity being taken as 4.0.

TABLE 6.—Estimate of the Larap and Calambayungan iron-ore deposits.

	Larap Peninsula.	Calambayungan Island.
Length of iron formation.....meters.....	700	480
Lateral extent along the dip.....do.....	100	100
Average thickness of ore.....do.....	7.3	4.8
Volume of ore.....cubic meters.....	511,000	230,000
Tonnage.....	2,040,000	920,000

In addition to these easily available resources, it may be possible to obtain considerable quantities from deeper levels; but these cannot be estimated until additional evidence regarding the dimensions of the ore bodies at deeper levels has been obtained by borings.

Appreciable quantities of ore can also be obtained from the surface boulders, already referred to. The amount, however, is not easily calculable owing to the irregularly scattered occurrence of these boulders. Some data bearing on the proportion of boulders in the surface soil have been obtained in the course of the trenching work. These are given in Table 7.

TABLE 7.—*Estimate of iron-ore boulders.*

Designation of trench.	Length.	Width.	Depth.	Volume.	Volume of boulders.	Boulders in soil.
	m.	m.	m.	cu. m.	cu. m.	Per cent.
Larap:						
1.....	15	1.3	1.7	33.1	3.0	9
1.....	12.4	1.3	1.7	27.4	14.9	55
1.....	47	1.3	1.5	91.6	30.0	33
2.....	34	1.3	1.8	79.6	27.2	34
2.....	19	1.3	2.2	54.3	19.0	35
9.....	22	1.3	2.0	57.2	5.6	10
Average.....						29
Calambayungan Island:						
A.....	20	1.3	2.0	52.0	13.0	25
G.....	12	1.3	2.2	34.0	5.8	17
H.....	15	1.3	1.5	29.0	14.5	50
H.....	11.7	1.3	2.0	30.0	12.0	40
I.....	13	1.3	1.7	28.7	14.5	50
I.....	24.5	1.3	1.7	54.1	4.8	9
I.....	34	1.3	1.0	44.2	3.4	8
K.....	19.5	1.3	1.6	40.4	8.2	20
K.....	24.0	1.3	1.3	40.6	4.8	12
Average.....						26

From Table 7 it is seen that, in the surface layers near the crest of the ridge, through which the trenches have been cut, the percentage of boulders varies within very wide limits, the average being 29 per cent for the Larap Peninsula and 26 per cent for the Calambayungan Island. These figures, however, are probably too high to be applied directly to the whole of the boulder areas, since the frequency seems to be considerably greater near the outcrop zone along the crest than farther down on the flanks. Very likely 15 to 20 per cent will prove to be nearer the mark.

Owing to the dense vegetation, the tracing of the extent of the various boulder areas offers considerable difficulty. Moreover, the thickness of the ore-bearing clay can, for the most part, only be conjectured. Table 8 records the results of an attempt to arrive at an estimate of the minimum amount available.

TABLE 8.—*Estimate of boulders.*

Boulder area.	Area.	Depth.	Volume of soil mass.	Boulders.	Volume of boulders.
	<i>sq. m.</i>	<i>m.</i>	<i>cu. m.</i>	<i>Per cent.</i>	<i>cu. m.</i>
Larap, Superior.....	^a 6,400	1	6,400	15	960
Larap, Busser.....	^a 5,000	1	5,000	15	750
Do.....	^b 20,000	2	40,000	20	8,000
Do.....	^c 20,000	1	20,000	15	3,000
Calambayungan Island.....	20,000	1	20,000	15	3,000
Total.....					15,710

^a Beach.^b Along the eastern slope.^c Along the western slope.

Multiplying the volume of the boulders, 15,710 cubic meters, by the specific gravity, 4, we arrive at a total of about 60,000 tons. It must, however, be pointed out that the depth (or thickness) of the ore-bearing clay layer seems to be highly variable, so that no reliable average figure can be stated. The figures here assumed are safe minima; and, therefore, it may well happen that the actual amount of ore contained in the boulder deposits will turn out to be double the estimated amount, or more.

ILLUSTRATIONS

PLATE 1

Map of the Larap and Calambayungan iron-ore deposits.

PLATE 2

Cross sections of the Larap and Calambayungan iron-ore deposits. A to K, Calambayungan Island; 1 to 15, Larap Peninsula.

PLATE 3

- FIG. 1. Large boulders of iron ore. Northwest point of Calambayungan Island.**
2. Rock of solid iron ore, showing on weathered surface the original bedding of replaced sedimentaries.

PLATE 4

- FIG. 1. A steep cliff of iron ore at trench 5, on the eastern flank of Larap ridge.**
FIGS. 2 and 3. Trenches with test pits, on Larap Peninsula.

TEXT FIGURES

- FIG. 1. Map of southern Luzon, showing the location of the Mambulao region.**
2. Map of the Mambulao region, after the United States Coast and Geodetic Survey.

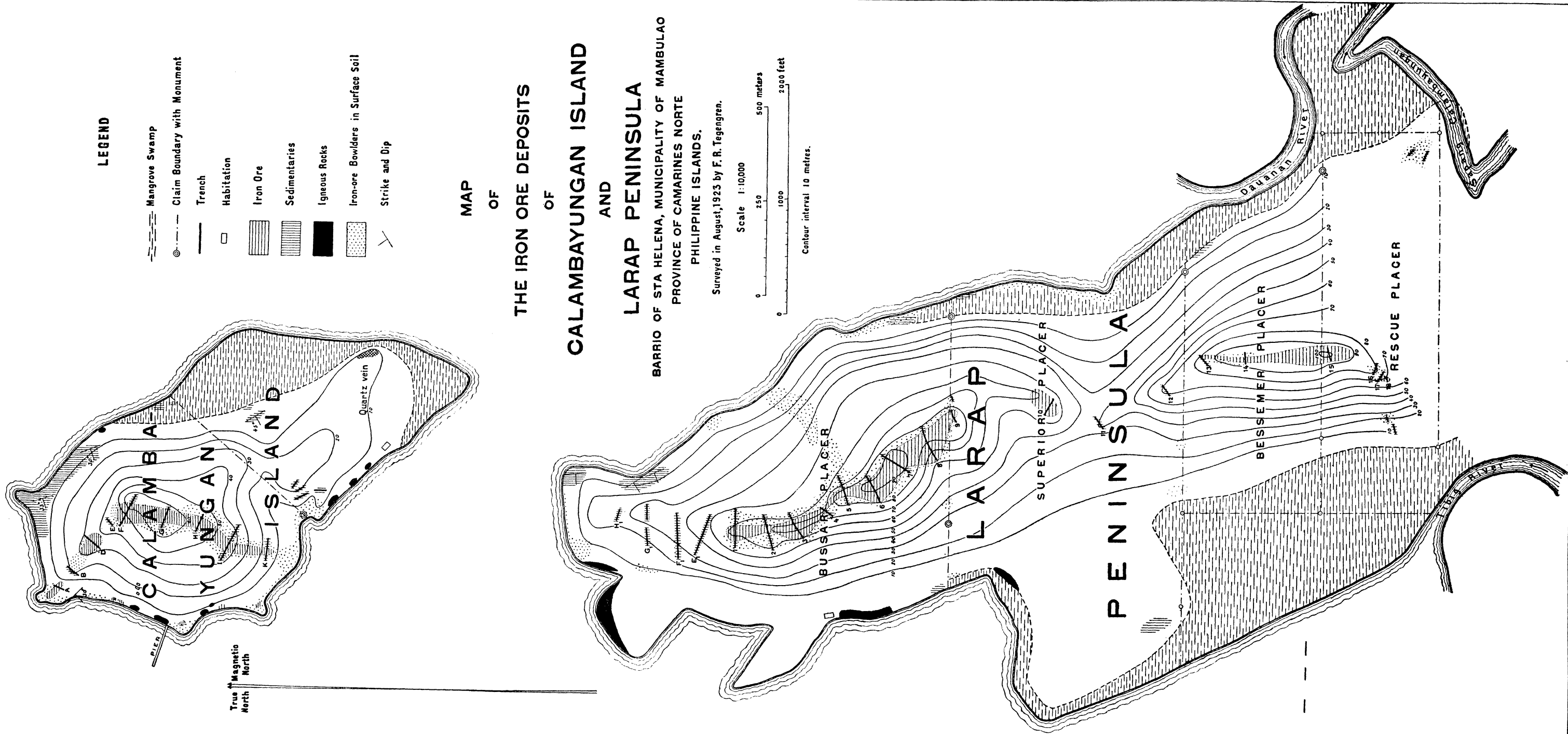


PLATE 1. LARAP PENINSULA AND CALAMBAYUNGAN ISLAND, SHOWING LOCATION OF THE IRON-ORE DEPOSITS.

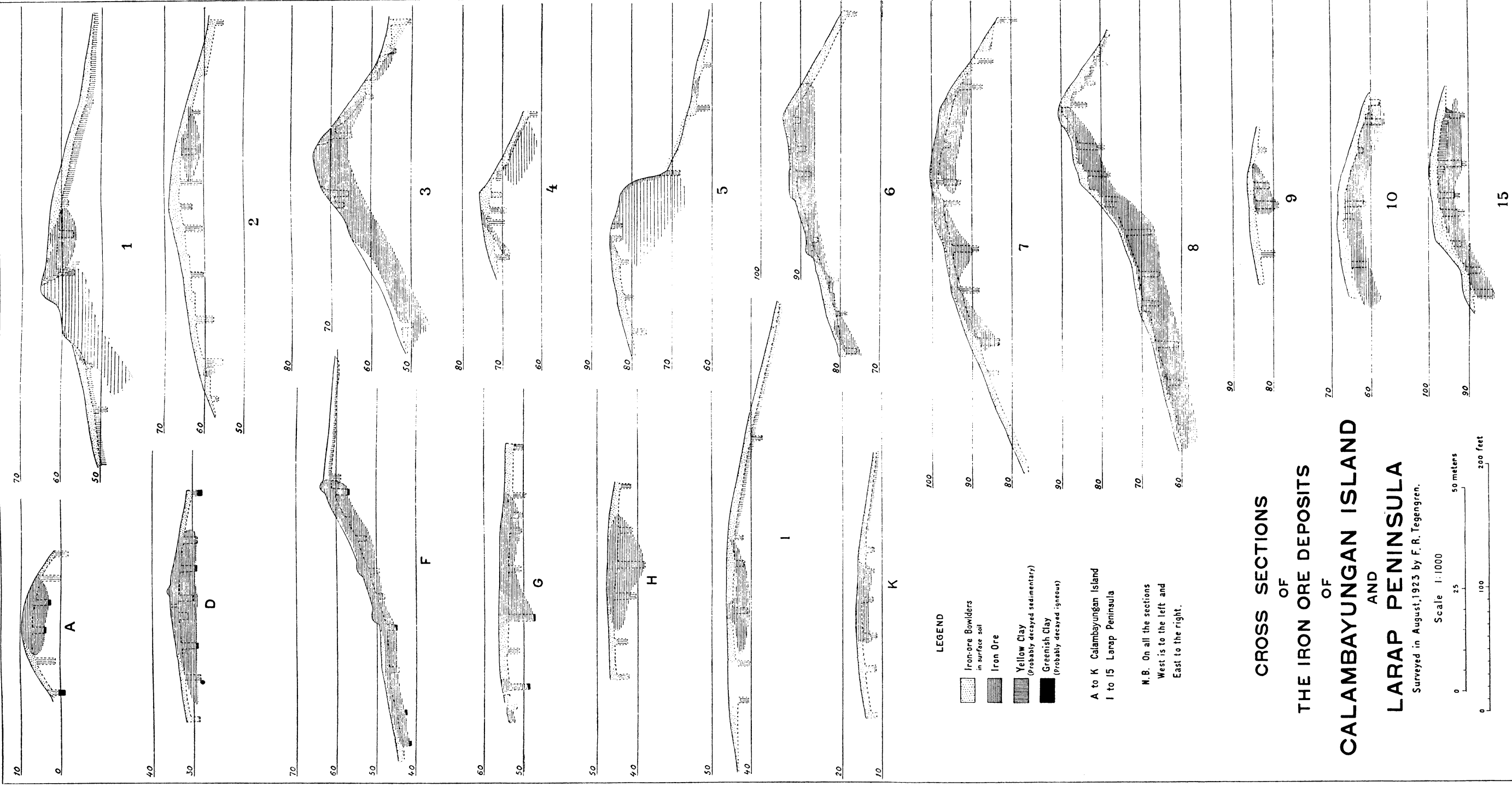


PLATE 2. CROSS SECTIONS OF THE LARAP AND CALAMBAYUNGAN IRON-ORE DEPOSITS.



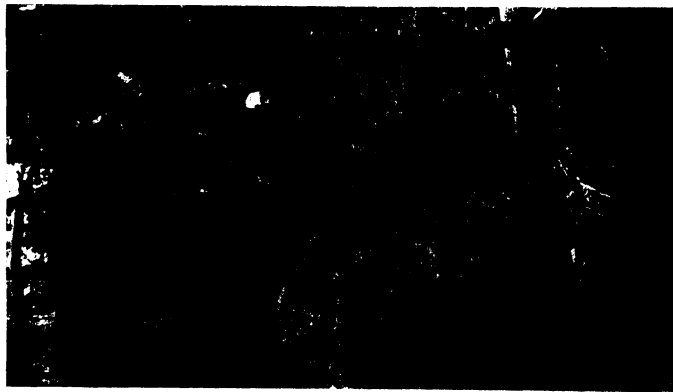


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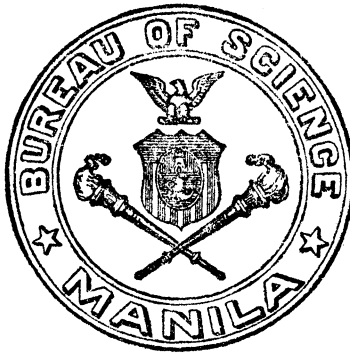
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A PHARMACOGNOSTICAL STUDY ON *DATURA ALBA* NEES AND *DATURA FASTUOSA* LINNÆUS FROM THE PHILIPPINES

By JOSÉ K. SANTOS

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and of the Bureau of Science, Manila*

SEVEN PLATES

The genus *Datura* of the natural family Solanaceæ contains about ten species of plants distributed throughout the tropical and temperate regions. All are regarded as highly poisonous and some of them have been used for centuries for both criminal and medical purposes, especially in India and in the southern part of China. Of the ten species under this genus only two are found in the Philippines; namely, *Datura alba* Nees and *D. fastuosa* Linnæus. They are herbaceous plants about 1.5 meters high, and are commonly known as *talong-punay puti* and *talong-punay itim*, respectively, or *kachubung* in Visayan. The former grows throughout this country, in waste places, while the latter is generally cultivated, and both are extensively distributed in the Indo-Malayan Region, tropical Africa, and America; they are cultivated in the southern part of Europe. Merrill(10) believes that they may be of prehistoric introduction.

Safford,(11) working critically on the genus *Datura*, came to the conclusion that the true *Datura metel*, described by Linnæus in the first edition of his Species Plantarum, is a species based upon the Asiatic metel nut, or "jouz-methel," which was used as a narcotic by the Arabs, Persians, and Hindoos long before the discovery of America. He claims that *D. fastuosa* was a

form of this species but, because of its purple color and the reduplication of the corolla, it has been set apart as a distinct species, while the white-flowered form was rechristened *D. alba*.

Interesting accounts regarding the ancient knowledge of the properties of *Datura alba* Nees and *D. fastuosa* Linnæus are found in Arabic, Sanskrit, and Indian literature, which fully establish their uses from the remotest antiquity.

Flückiger and Hambury,(5) Ford and Crow,(6) and Watt(13), (14) give a rather complete description of the history, properties, uses, etc., of the two forms found in China and India. Many cases of poisoning with criminal intent are cited.

In the Philippines also the two plants, the white-flowered and the purple-flowered, have long been known for their medicinal and poisonous properties. The flowers are smoked as a remedy for dyspnea in bronchitis. Bowman(2) reported a severe case of poisoning from the seeds of *Datura alba* of this country and mentioned symptoms similar to those described in cases of poisoning in India.

The leaves of *Datura alba* are official in the French, Japanese, and Indian Pharmacopœias, and the leaves and seeds are official in the British Pharmacopœia. *Datura fastuosa*, or the black datura, has always been considered the more powerful or more poisonous of the two; but, according to the Pharmacopœia of India, there is no evidence that this is so, and probably both contain an equal amount of the active principle.

In connection with the active constituents Browne(3) in 1896 reported that the flowers of the Chinese *Datura alba* contain 0.485 per cent of alkaloid calculated as hyosine. Hesse(9) in 1900, however, working with flowers provided by Browne, obtained 0.55 per cent of total alkaloids of which approximately 92 per cent was hyosine, 6 per cent hyoscyamine, and 2 per cent atropine. Bacon(1) in 1906 obtained 0.465 per cent of total alkaloid from the air-dried seeds of the Philippine *Datura alba*, 0.21 per cent from air-dried leaves, and 0.17 per cent from air-dried wood and roots. Brill(4) in 1916 conducted a series of experiments upon the active principles of the same plant and obtained a greater percentage of total alkaloid than Bacon did. He claimed that prolonged drying and heating at high temperatures caused loss of the alkaloid.

In 1922, Garcia and Guevara(7) conducted very interesting experiments on the pharmacodynamics of *Datura alba* Nees and came to the conclusion that the effects of toxic doses in dogs and cats correspond to those produced in man. In large

doses it produces excitement, then incoördination and, lastly, depression with a tendency to sleep. These symptoms agree with those described by Tavera.(12)

It is strange, however, that the anatomical structures of such important plants as *Datura alba* Nees and *D. fastuosa* Linnæus, which have been fully recognized for centuries because of their valuable medicinal properties and as a poison, have received but little attention. It seems, therefore, that a critical pharmacognostical study of the two plants upon which the identification of the drug can be based is desirable.

MATERIALS AND METHODS

The materials used for the investigation of *Datura alba* were collected from wild plants growing about Manila and from cultivated ones in the botanical garden of the University of the Philippines. The sections used for *Datura fastuosa* were prepared from seeds collected from Puerto Galera, Mindoro, and from cultivated plants in the University grown from the same lot of seeds.

All the sections used were prepared from fresh material and cut from 20 to 50 μ thick by means of a sliding microtome. Some were mounted in a dilute solution of glycerine, some in a dilute solution of chloral hydrate, and some were stained with safranine, contrasted with hæmatoxylin, and mounted in balsam. For the detailed study of the seed coat, Schulze's maceration process as indicated by Greenish(8) was employed.

DATURA ALBA NEES

The leaves.—The full-grown leaves are from 9 to 18 cm long and from 7 to 14 cm wide. They are ovate to oblong-ovate in outline, petiolate, nearly glabrous, and when fresh are dark green in the upper surface and light green in the lower surface (Plate 1, figs. 1 and 2). The base is unequal, one side extending 3 to 12 mm below the other, but occasionally is even and rounded. The margin is irregularly and shallowly lobed. The lobes vary in number from two to five on each side of the leaf, and have rather obtuse or sometimes slightly rounded tips. The apex of the leaves is generally acuminate, but occasionally shortly pointed. The petioles are from 6 to 12 cm in length, nearly cylindric, shallowly grooved on the upper part, and light green like the midrib and veins. On the projecting midrib there are veins of the first order, four or five in number, diverging from it at an angle of 30 to 75 degrees, dividing near the margin, and

the outer lateral branches passing into the lobes. The other lateral branches of these primary and secondary veins anastomose with each other, forming a sort of network. When the fresh leaves are crushed between the fingers they throw off a somewhat disagreeable, narcoticlike odor. The taste is unpleasant, bitterish, and nauseating.

The young leaves are usually more or less entire and covered with rather thick hairs, but as they progress toward maturity they become more or less glabrous.

Structure of the leaf.—The leaf structure of *Datura alba* Nees in cross section is bifacial and has the general appearance of a cross section of the leaf of *Datura stramonium*, but differs from it in several respects (Plate 2, fig. 21). The mesophyll is rather uniform in thickness, which is about 0.35 mm. The upper epidermis is composed of a single layer of tangentially elongated and rectangular cells with thick and cutinized outer cell walls. The lower epidermis also consists of a layer of cells, of the same shape but with very much thinner and less cutinized outer cell walls. The palisade chlorenchyma occupies about one-third of the section and consists of a single row of perpendicularly elongated cells about 0.1 mm in length and 0.025 mm in diameter and formed just below the upper epidermis. In the lower part two or three of these cells communicate with one large cell which frequently contains a rosette-shaped crystal or a rosette aggregate of crystals of calcium oxalate, and can be called a crystal cell. The crystal cells form part of the spongy chlorenchyma region. They are characterized not only by their rosette-shaped crystal content but also by their relatively large size and comparatively isodiametric shape. They usually form a continuous row in the interneural region and form a part of the spongy region. They are about 0.041 mm in diameter (Plate 2, fig. 21 *cr*). The spongy chlorenchyma region is made up of spongy parenchyma cells of various forms and sizes, but in general they are more or less elongated with a slightly wavy outline and with few chloroplastids. This part of the mesophyll is a trifle wider than the palisade region, and is richly supplied with large air spaces. Epidermal outgrowths are observed on upper and lower sides consisting of (a) warty, uniserial, articulated, nonglandular hairs of 3 to 5 cells and from 0.6 to 0.9 mm in length, and (b) glandular hairs with a slightly bent, 1-celled stalk and with a 4- to 6-celled secreting head. The capitate part or gland is usually globose in outline, and is mostly 4-celled. These glandular hairs measure from

0.06 to 0.08 mm; the stalk is 0.035 mm long, and the diameter of the gland is about 0.034 mm.

In the surface preparations the upper epidermal cells appear polygonal in outline with slightly wavy or undulate thick walls, and are from 0.054 to 0.095 mm in length and from 0.036 to 0.05 mm in width. The lower epidermal cells are also more or less polygonal in outline, but their walls are thinner and distinctly undulate-sinuate (Plate 2, figs. 22 and 23). The stomata are more numerous in the lower surface and vary from 0.029 to 0.036 mm in length and from 0.016 to 0.026 mm in width, and three or four and, occasionally, five neighboring cells surround them. One of the neighboring cells is invariably smaller than the others, and this smallest neighboring cell is usually applied vertically to the length of the guard cells. The glandular and nonglandular hairs are better noted in these preparations. They are more abundant in the lower surface, particularly along the sides of the veinlets.

When the surface sections are cleared with an aqueous solution of chloral hydrate the epidermal cuticle is observed to be distinctly striated. This striation of the cuticle is more evident on the lower surface than on the upper. The striated lines all run in a given direction (that is, parallel to the longest side of the epidermal walls) and apparently converge to the base of simple hairs or sometimes are perpendicular to the length of the guard cells of the stomata, as represented in Plate 3, figs. 24 and 25.

The midrib is convex above and strongly convex below (Plate 2, fig. 21). The ventral epidermis as well as the dorsal consists of a single layer of nearly isodiametric cells, square or nearly circular in outline. Occasionally they are somewhat radially elongated, particularly those of the lower side. They are from 0.015 to 0.04 mm in diameter. The outer cell walls of the upper epidermis are comparatively thicker and more cutinized than are those of the lower epidermis. The stomata and the glandular and nonglandular hairs are found in both the upper and the lower epidermis. The collenchyma cells are present in two distinct groups, above and below the midrib. In the inner part of these cells toward the stele is a region of cortical parenchyma consisting of several rows of large cells, 0.03 to 0.09 mm in diameter, some of which are filled with very abundant sphenoidal microcrystals of calcium oxalate; the rosette, prismatic, or rhomboid crystals are also seen, but they are less numerous. The endodermis is not distinct. The meristele is

somewhat crescent-shaped or it appears as a flat arc in outline. The xylem is composed of large vessels, from 0.02 to 0.05 mm in diameter, and is provided with bast in the exterior part above and below, which is a constant characteristic of plants belonging to the family Solanaceæ. Neither sclerenchymatous elements nor pericycle fibers are found in the bast.

The petiole.—The structure of the petiole in cross section is very similar to that of the midrib, except that the outline of the petiole is somewhat circular. There is only a slight indication of the shallow groove found along the upper part of the petiole. The principal meristele has a U shape. Near the region corresponding to the upper lateral side of the groove there appear two apparently isolated incipient vascular bundles, one on each side of the raised part, consisting of xylem and phloëm. The central upper portion of the groove corresponding to the convex upper side of the midrib is slightly convex, and contains typical subepidermal collenchyma cells.

The flowers are very large, white, solitary, axillary, and shortly pedicelled in the forks. They are from 12 to 18 cm long. The pedicel is green, terete, and from 6 to 10 mm long. The calyx is about 6.5 cm long or more, pale green, thin, slightly hairy, tubular, with five short, more or less triangular lobes, from each of which a distinct ridge runs down to the base. It is deciduous by a transverse circular fission or cleavage near the base, the upper, thinner portion falling off, while the thicker, small, basal part remains persistent with the fruit (Plate 1, fig. 1).

The corolla in the bud is longitudinally plicated. When expanded it is white, slightly fragrant, tubular-funnel-shaped, 15 to 18 cm long and 10 cm wide at the mouth. It has five plaits and five spreading or recurved lobes. The lobes are somewhat rounded, but their middle parts are provided with acuminate, almost filiform, cuspidate points, from 1 to 2 cm in length. When the young ovary begins to divide into nodes the corolla gradually separates at the very base and falls off together with the five epipetalous stamens and the deciduous calyx.

There are five stamens, inserted in the corolla tube; the anthers are elongated, flattened, dorsifixed, hairy, from 14 to 16 mm long, and dehiscing longitudinally (Plate 1, figs. 3 and 4). The filaments are about 14 cm long. The pollen grains are globular or sometimes ovoid, whitish, finely striated, and from 0.035 to 0.05 mm in diameter when dry and from 0.065 to 0.075 mm when mounted in water (Plate 1, figs. 5a, 5b).

The pistil is characterized by the very long, filiform, whitish

style, which is from 12.5 to 18 cm in length; by the bilateral or bilobed blunt stigma, which is about 5 mm long; and by the superior, conical, 2-carpelled ovary, which is seated on a disk of the nectary gland and covered with somewhat erect processes (Plate 1, fig. 6).

The ovary is 2-celled above and imperfectly 4-celled below, due to the outgrowth of a false dissepiment from the dorsal suture of the carpels to the axile placentæ (Plate 1, figs. 7 and 8). Ovules anatropous, very numerous, and arranged in a very irregular manner.

Surface preparation of the calyx and corolla.—The outer epidermal cells of the calyx have the general appearance of the upper epidermal cells of the leaf, except that they are smaller. They are more or less polygonal in outline, 0.018 to 0.075 mm in length, and 0.018 to 0.036 mm in width. The stomata are numerous and vary from 0.03 to 0.4 mm long and from 0.02 to 0.025 mm wide. Both glandular and nonglandular hairs are present. The glandular hairs, like those found on the leaf, consist of a slightly bent, 1-celled stalk with four to eight secreting head cells; the usually bent nonglandular hairs are 0.15 to 0.25 mm long and composed of three or four warty cells (Plate 3, fig. 26). The inner epidermal cells are also somewhat polygonal in outline, but are larger and have thinner and distinctly undulate cell walls. They are from 0.036 to 0.124 mm in length and from 0.018 to 0.072 mm in width. The stomata are also present, but are comparatively larger and less numerous, and some of them are aborted at different stages. The fully developed stomata are from 0.04 to 0.055 mm in length and from 0.03 to 0.035 mm in width. The two kinds of hairs are not found on the inner side of the calyx (Plate 3, fig. 27).

The outer and inner surface views of the corolla are practically the same in appearance. The cells are polygonal in outline, 0.029 to 0.072 mm in length and 0.022 to 0.036 mm in width, and have slightly undulate thin walls (Plate 3, fig. 28). Both glandular and nonglandular hairs are present on the two sides. There are two kinds of glandular hairs, however, one with the same characteristics as those already described in the leaf and calyx (Plate 3, fig. 29); another with a 3- to 5-celled stalk, in which the basal cell is strongly developed and has a single terminal secreting cell, as indicated in Plate 3, figs. 30 and 31. The latter type of glandular hairs is seen only on the corolla. They are comparatively longer than the nonglandular hairs of the leaf and have large basal cells with thick walls.

These glandular hairs are about 0.3 mm in length, and their basal cells are about 0.04 mm in diameter.

The fruit.—The fruit is globose or sometimes ovoid, about 3.5 cm in diameter, nodding, green, covered with short, stout spines, and surrounded at the base by the enlarged and usually reflexed persistent base of the calyx. It is distinctly and practically bilocular, although the 2-axiled placentæ project into the interior of the loculi. No secondary dissepiment extends in the part between the fleshy placentæ and the opposite wall of the fruit. The pericarp is fleshy, soft, and easily disintegrated when pressed between the fingers. It is always apically or subapically dehiscent into four or more irregular valves, as indicated in Plate 1, fig. 9.

The seeds.—The mature seeds of *Datura alba* Nees are light yellowish brown, very irregular in shape, somewhat shriveled, flattened, and have the general appearance of the human ear. Sometimes they are obscurely triangular or subreniform in outline, one end smaller than the other (Plate 1, figs. 10 and 11). They are from 5 to 6 mm long, 4 to 5 mm wide, and 1.5 to 2 mm thick. The dorsal side or rounded end is thickened and distinctly sinuous, convoluted, double- or triple-ridged, with one or two deep grooves along the middle part. The hilum is rather prominent and, when fresh, is white. It runs from the pointed or micropylar end to nearly half the length of the seed. The outer surface of the testa, as seen under the hand lens, exhibits fine rugosities but is not prominently pitted.

Microscopical structure.—A median longitudinal section of the seed, cut in a plane parallel to the flattened surface, as represented in Plate 1, fig. 12, a diagrammatic drawing made under the objective 48 mm and eyepiece $\times 2$ with the aid of a camera lucida, shows at least four distinct regions; namely, the seed coat region; the endosperm region, which is somewhat reniform in outline; the coiled embryo, which is extended around the peripheral side of the endosperm and shows the two bent cotyledons, the plumule, and the radicle; and the hilum, which is located toward the pointed or micropylar end of the seed. To these four regions the perisperm may be added, which under a higher magnification can be seen between the seed coat and the endosperm. In a more or less transverse or oblique section, cut at right angles to the flattened surfaces and somewhat obliquely to the long axis of the seed, only three of these important regions are seen in Plate 1, fig. 13. The section appears as oblong-elliptic in outline, slightly constricted at the

middle, and coarsely crenated at the two ends, corresponding to the ventral and dorsal parts of the seeds. The crenation is simply due to the folding of the epidermal layer at the two regions where the epidermal cells are greatly elongated. The epidermis corresponding to the flat surfaces is comparatively thinner, and the length of the epidermal cells gradually increases toward the two ends. The endosperm is also oblong-elliptic, and somewhat constricted at the middle part. The embryo is cut into two pieces. Toward the dorsal region of the endosperm the cross section of the radicle is found; and toward the ventral side, the transverse section of the two cotyledons.

Careful examination of thin sections of the seed reveals that the region of the seed coat is differentiated into three somewhat distinct layers; namely, the outer layer, or testa, the layer next to the testa, and a layer made up of collapsed or obliterated parenchyma cells.

The outer layer, which constitutes the testa, consists of a single row of radially and tangentially elongated, thick-walled, greatly lignified, and tangentially pitted cells. Its external part is lined with a thin layer of a hyaline substance of mucilaginous nature. In the transverse or longitudinal section cut parallel to the plane of the flat surface of the seed, these cells appear very irregular in outline. They vary from isodiametric to rectangular or bottlelike or stonelike cells with a minute projecting outgrowth toward the outer and inner ends. Their walls are sinuously bent in and out in the direction of their length as shown in Plate 1, figs. 14 and 17. The cells that correspond to the flattened side have the general characteristics and shape of the ordinary stone cells, with distinctly striated thick walls and small cavity. Sometimes they are tangentially compressed or elongated, papillate or with minute processes in the outer part like the other cells of the testa (Plate 1, fig. 16).

In surface view the elongated cells as well as the flattened ones are polygonal in outline and appear indented with one another. Their walls are wavy and distinctly striated. The indentations of the cells are found to be somewhat interlacing along the middle lamella, and appear as very minute, thick-walled cells, elliptic in outline, as illustrated in Plate 2, fig. 19. The transverse sections of the seed coat cut tangentially to the dorsal part of the seed show that the very thick, lignified cell walls are closely fitted to each other with a distinct, middle lamella, striated and differentiated into two regions. The sections made toward the outer part show that the cells have

thinner walls, and eventually larger cavities; on the other hand, in the sections cut through the middle part of the cells corresponding to the constricted region, the cells have a smaller cavity and very thick walls. Figure 20 (Plate 2) is drawn from the tangential sections of the dorsal side of the seed.

When this outer layer of the testa is macerated by Schulze's maceration mixture, the individual cells exhibit great diversity in size and form. The cells from the flattened regions of the seed are easily identified as they are very short and very irregular in outline. They are from 0.08 to 0.18 mm in diameter and from 0.15 to 0.21 mm in length. The stonelike cells, besides exhibiting the general characteristics already described, show that their cell walls are almost uniformly thickened all around and more or less distinctly striated, and they have very small lumens, or cavities. The cup-shaped, or beakerlike, cells are more regular in shape and somewhat rectangular in outline. They are usually slightly constricted at the middle part. Their cell walls are also transversely pitted, striated, and greatly thickened in the lateral parts, particularly at the constricted region, but they gradually become thinner toward the two ends of the cells where the indentations or processes are observed. The epidermal cells corresponding to the corrugated or convoluted regions of the seed are radially elongated, more regular in outline, and all are transversely pitted. They are 0.082 to 0.18 mm in diameter and from 0.285 to 0.378 mm in length. These cells also appear cup-shaped and are indented in both outer and inner ends like the other type of cells found in the flattened side of the seed, except that they are more elongated and more constricted in the middle part. Sometimes the constriction is extended toward the base, and the cells simulate a certain kind of flower base or are somewhat like a funnel, as shown in Plate 2, fig. 18, *a* to *g*. Their side walls are distinctly striated and greatly thickened, particularly toward the constricted part, but gradually become thinner toward the transverse walls. The pits, which run transversely, occur in the thickened part, but they are more abundant toward the thinner walls. The reticulate markings or the scalariform thickenings are frequently observed among the large cells. They are transversely arranged throughout the entire length of the cells. A microchemical test upon the walls of these cells of the testa showed that they are lignified.

The layer next to the testa consists of two or more rows of parenchyma cells with thin, delicate, and slightly wavy cell

walls (Plate 1, fig. 14p). They are more or less isodiametric and rather well preserved, with somewhat triangular intercellular spaces at the point of meeting of three adjacent cells.

The third layer of the seed coat is made up of collapsed or obliterated parenchyma cells, with extremely thin and delicate cell walls (Plate 1, fig. 14op). On account of the compactness of their walls, it is difficult to determine either the structure of the individual cell or the number of rows of these cells that form this layer.

The perisperm.—Between the layer of the obliterated parenchyma of the seed coat and the epidermis of the endosperm is a single row of rather tangentially elongated or somewhat rectangular thin-walled cells. These cells are the remains of the nucellus and they are more or less hyaline in nature. They constitute what is known as perisperm, which closely adheres to the outer part of the endosperm (Plate 1, fig. 14pe).

The endosperm.—The endosperm is composed of rather large, nearly isodiametric cells with fairly thick walls, mostly polygonal in outline, and filled with rather large aleurone grains, and sometimes with oil globules. The cells toward the periphery, however, are radially elongated, as shown in Plate 1, fig. 14e (a drawing made from a transverse section) and fig. 15 (a cell drawn from the middle part of the endosperm, greatly enlarged, showing aleurone grains and oil globules). Within the endosperm the sections of the embryo are embedded. The cross section of the radicle is circular in outline, and is composed of young, undifferentiated tissue consisting of parenchyma cells filled with small aleurone grains. The region occupied by the cortex and that occupied by the stele are very distinct, while the transverse sections of the cotyledons are somewhat elliptic in outline and are obscurely differentiated into epidermis, palisade and spongy parenchyma, and rudimentary vascular bundles. The cells are isodiametric and also filled with small aleurone grains, as are those of the radicle (Plate 1, fig. 13).

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The leaves.—The mature leaves are from 8 to 17 cm long and from 6 to 12 cm wide. They are ovate in outline, petiolate, glabrous, and dark green on the upper surface and light green on the lower surface (Plate 4, figs. 33 and 34). The margin is entire or sometimes slightly lobed. The lobes vary from one to three or more, with obtuse or rounded tip. The base is unequal, one side extending from 4 to 17 mm below the other.

The apex is generally acuminate and sometimes acute. The petioles are from 3 to 8 cm in length, nearly cylindrical, shallowly grooved on the upper part, and purple in color or sometimes greenish spotted with purple. The projecting midrib and the four or five veins of the first order are entirely purple or sometimes only spotted with this color. These veins diverge from the midrib at an angle of 30 to 50 degrees and divide near the margin. The secondary veins and the veinules anastomose, forming a sort of network. The fresh leaves, when crushed between the fingers, like the fresh leaves of *Datura alba*, throw off a somewhat disagreeable narcoticlike odor. The taste is unpleasant, bitterish, and nauseating.

The leaves of *Datura fastuosa* are darker and rather smaller and thinner than those of *Datura alba*. The margins of the former are very shallowly lobed and sometimes they are entire, while those of the latter are usually lobed, and the lobes are distinct.

Structure of the leaf.—The leaf structure of *Datura fastuosa* is very similar to that of *Datura alba* (Plate 6, fig. 62). The only difference is that the mesophyll of the former is thinner and the palisade chlorenchyma cells are smaller, from 0.05 to 0.07 mm in length and about 0.02 mm in diameter. Both glandular and nonglandular hairs are present in the upper and lower surface of the leaf. These hairs differ from the hairs of *Datura alba* in that the stalk of the glandular hair is usually straight and sometimes consists of two cells, while that of *Datura alba* is slightly bent and usually consists of a single cell; the nonglandular hairs of *Datura fastuosa* are generally shorter than are those of *Datura alba* (Plate 7, figs. 63 and 70).

In the surface preparations mounted in dilute glycerine, the upper epidermal cells of *Datura fastuosa* appear practically like the upper epidermal cells of *Datura alba* as shown in Plate 7, figs. 63 and 64. In the lower epidermis the cells of the former are larger than are those of the latter and they have thinner and more-wavy cell walls. The stomata are also less numerous and they vary from 0.12 to 0.165 mm in length and from 0.09 to 0.1 mm in width.

In the surface preparation cleared with a dilute solution of chloral hydrate the epidermal cuticle is observed to be more striated than is that of *Datura alba*, as shown clearly in Plate 7, figs. 65 and 66.

The structure of the midrib coincides in every respect with that of *Datura alba*, except that the vessels are slightly smaller,

and the sphenoidal microcrystals and the prismatic crystals of calcium oxalate are more abundant (Plate 6, fig. 62).

The petiole.—I failed to find any significant differences in the structure of the petioles of the two plants. Both have practically the same distribution of tissues and the vessels are very similar.

The flowers.—The flowers of *Datura fastuosa* are strikingly different from those of *Datura alba*. They are very large, with double or triple corolla, purple, solitary, in the forks, and shortly pedicelled. They are from 16 to 19 cm long. The pedicel is purple, or sometimes greenish purple on one side, terete, and from 4 to 8 cm long. The calyx is about 5.5 cm long, greenish, with numerous elongated purple spots which occasionally unite and form a large purple area. It is thin, slightly hairy, tubular, with five short, more or less triangular lobes, from each of which a distinct ridge runs down to the base. Like that of *Datura alba*, it is deciduous by a transverse circular fission or cleavage near the base, the upper thinner portion falling off, while the thicker, small, basal part remains persistent with the fruit like a ring (Plate 4, figs. 33 and 35).

The corolla is the most variable part of the purple-flowered *Datura*. In the bud it is plicated, but when expanded it is tubular-funnel-shaped, 15 to 18.5 cm long, and about 6 cm wide at the mouth. The upper outer surface is violet or dark purple, which color gradually becomes lighter toward the lower part and finally greenish white at the base, while the inner surface is white. It is usually doubled or tripled, and sometimes in the latter form between the second and third corolla there are linear appendages or petal-like structures like those shown in Plate 4, figs. 36 and 37. The outer corolla is usually separated or free from the inner ones, which are always united near the base. The corolla has five plaits and five more or less convoluted lobes with acuminate, filiform cuspidate and twisted points which are about 2 cm long. When the corolla begins to bend downward, as in the case of *Datura alba*, it gradually separates at the very base and falls off together with the five epipetalous stamens and the deciduous calyx.

The five stamens inserted in the corolla tube have elongated, somewhat flattened, dorsifixed, hairy anthers, 14 mm long, which dehisce longitudinally (Plate 4, figs. 36 and 38). The filaments are filiform, about 15 cm long. The pollen grains have the general appearance of those of *Datura alba*, are finely striated and from 0.032 to 0.05 mm in diameter when dry and about 0.07

mm in diameter when mounted in water (Plate 4, figs. 39a and 39b).

Many abnormalities were observed in the development of the flowers of *Datura fastuosa* which I have never observed in those of *Datura alba*. The corolla tube is sometimes folded and twisted at the middle part. This happens while the corolla is still inclosed by the calyx, so that as a result, when it begins to expand, the calyx is burst or split down one side, as shown in Plate 5, figs. 46 to 50. From the early stage of the corolla, especially when it commences to protrude from the calyx, it can be predicted whether it will be a normal or an abnormal corolla, because of the irregularity of the diameter of the calyx (Plate 5, figs. 48, *a* and *b*). The abnormally borne flowers are always smaller than the normal ones and their stamens are usually abnormal, as shown in Plate 5, figs. 50, *a* and *b*. Occasionally the stamens are united at the base, and frequently the filaments are provided with appendages, or winglike structures (Plate 4, figs. 43 and 44; Plate 5, figs. 49, *a* and *b*), but the anthers are not affected by this abnormality. A very serious case of the abnormally borne flower is shown in Plate 5, fig. 47, where the outer corolla is also burst at one side near the base, and the folded and twisted part of the inner corolla is protruded, together with the stamens in it.

The pistil is filiform, whitish or sometimes purplish, and about 14.5 cm long, while the bilateral stigma is about 6 mm long. It is apparently not affected by the abnormalities just mentioned, and the vitality of the ovary is not lost (Plate 4, fig. 40).

The ovary is covered with flat processes and these are usually less numerous than those observed in *Datura alba*. It is also 2-celled above and imperfectly 4-celled below, as shown in Plate 4, figs. 41 and 42.

The surface preparation of the calyx and corolla.—In structure the outer and inner surfaces of the calyx agree well with those of the calyx of *Datura alba*. Only slight difference is observed in the size and shape of hairs and stomata and in the thickness and outline of the inner epidermis. The nonglandular hairs of *Datura fastuosa* are shorter, consist of two to four cells, and are mostly straight. They are from 0.1 to 0.15 mm long and are not very abundant. The stomata are elliptic and from 0.025 to 0.045 mm long, 0.025 to 0.030 mm wide. The cell walls of the inner epidermis are more wavy and are thinner than those of *Datura alba* (Plate 7, figs. 67 and 68).

The epidermal cells of the corolla have thinner and more-wavy cell walls than have those of *Datura alba*. Both glandular and nonglandular hairs are observed. The long-stalked, glandular hairs are 0.15 to 0.4 mm long, and the cell walls of their two basal cells are not thickened, as shown in Plate 7, fig. 69.

The fruit.—The fruit is almost identical with that of *Datura alba* in shape, size, structure, and method of dehiscing, except that it has usually a smaller number of spines, or sometimes is spineless and smooth (Plate 4, fig. 45; Plate 5, fig. 46). Frequently its spines are confined simply to one side and it is smooth on the other side, particularly near the apex. The fruits derived from the abnormally borne flowers, however, are generally smaller than those developed from the normal ones.

The seeds.—The seeds of *Datura fastuosa* are thinner, flatter, and rather darker than are those of *Datura alba*. They are pale brown, discoidally auriculiform, 5 to 6 mm long, 4 to 5 mm broad, and 1.2 to 1.6 mm thick (Plate 6, figs. 51, *a* and *b*). When fresh, the fleshy outgrowth at the base is white and extends from the micropylar end to a little beyond half the length of the seed. The testa is rough, tough, and shriveled, with conspicuous double or triple convolutions and one or two main grooves along the dorsal side. Under the hand lens the outer surface of the testa is finely rugose, but is not distinctly pitted.

Microscopical structure.—Sections of the seeds of *Datura fastuosa* corresponding to the longitudinal and transverse sections of *Datura alba* seeds show the same characteristics and distribution of tissues observed in the latter (Plate 6, figs. 52 and 53). The indefinite embryo of *Datura fastuosa*, however, although its characteristic curvation is similar to that of *Datura alba*, can be easily differentiated from the latter by the fact that the tips of the pair of cotyledons of the embryo of *Datura fastuosa* and the lower end of the radicle are always very close together and almost touch each other.

In a critical study, however, made on thin sections of the seed-coat region, endosperm, embryo, hilum (and including the perisperm), as shown in Plate 6, figs. 54 to 60, I found that the structure of these regions is essentially the same as is the structure of the corresponding regions described in *Datura alba* seeds. The individual cells isolated by Schulze's maceration mixture exhibit the same characteristic markings on their walls and similar diversity in size and form. Although sometimes they appear rather smaller than the individual cells of *Datura*

alba, yet this variation in size cannot be relied upon as a diagnostic characteristic of the drug (Plate 6, figs. 61, *a* to *h*).

The calcium oxalate crystals.—The calcium oxalate crystals observed in the study of the two plants are rather similar in their general characteristics. They vary from very minute sphenoidal microcrystals, about 0.0025 mm long, to a large prismatic or monoclinic crystal, 0.05 mm long and 0.02 mm in diameter. The crystals of calcium oxalate found in the sections of the blade are usually two types of rosette; one is smaller, 0.012 mm in diameter and is made up of small sphenoidal microcrystals, as shown in Plate 3, fig. 32*b*, and Plate 7, fig. 74*c*, while the other is larger and is made up usually of larger, sphenoidal, prismatic or rhomboid crystals, as represented in Plate 3, figs. 32, *d* to *g*, and Plate 7, figs. 74, *e* to *h*. The rosette crystals of *Datura alba* are generally larger than are those of *Datura fastuosa* (Plate 3, fig. 32, and Plate 7, fig. 74). The crystals of calcium oxalate of the transverse section of the midrib are usually in the form of microcrystals which fill up some of the parenchyma cells in the upper and lower part of the vascular region (Plate 2, fig. 21, and Plate 6, fig. 62). There are also some rosette, prismatic, and rhomboid forms, but in *Datura fastuosa* the last-named forms are more numerous than in the sections of *Datura alba*.

SUMMARY AND CONCLUSIONS

1. Grown under the same conditions, the leaves of *Datura alba* are generally larger, thinner, more distinctly lobed, and lighter in color than those of *Datura fastuosa*, and the veins of the latter are purple.

2. The leaf structure of *Datura alba* is similar to that of *Datura fastuosa*, but the latter has a thinner mesophyll, shorter nonglandular hairs, and the stalk of the glandular hairs is usually straight and sometimes consists of two cells, while the stalk of the glandular hair of the former is slightly bent and usually consists of a single cell.

3. In the surface preparation of the leaf the lower epidermal cells of *Datura fastuosa* are larger and have thinner and more-wavy cell walls than those of *Datura alba*, and the stomata are less numerous than in the latter.

4. When the surface preparation is cleared with a dilute solution of chloral hydrate, the epidermal cuticle of *Datura fastuosa* is more striated than is that of *Datura alba*.

5. The cross section of the midrib of *Datura alba* has slightly larger vessels, and the sphenoidal microcrystals and prismatic

crystals of calcium oxalate are less abundant than are those of *Datura fastuosa*.

6. The flowers of *Datura alba* are white and slightly fragrant and the corolla is simple, with five spreading or recurved lobes, while those of *Datura fastuosa* are purple or violet on the outer surface and whitish on the inner surface. The corolla of the latter is usually doubled or tripled, with five convoluted lobes, and not recurved as in the former. Furthermore, the variability of the flowers of *Datura fastuosa* is not confined to the reduplication of the corolla, but also is noted in the production of appendagelike structures between the second and the third corollas, and also in the filament of the stamens in the abnormally borne flowers. This abnormality is not observed in the case of *Datura alba*.

7. The epidermal cells of the corolla of *Datura alba* have thicker and less-wavy cell walls than have those of *Datura fastuosa*, and the long-stalked, glandular hairs of the former are longer and provided with thick-walled basal cells, while those of the latter are shorter and the cell walls of the basal cells are thin.

8. The ovary of *Datura alba* is covered with numerous erect and pointed processes, while that of *Datura fastuosa* has few flattened processes.

9. The calyx of *Datura alba* is longer than is that of *Datura fastuosa*. That of the former is usually about half as long as the corolla tube, while that of the latter is about one-third of the corolla tube. The nonglandular hairs of *Datura alba* are longer than are those of *Datura fastuosa*.

10. The fruits of *Datura alba* are similar in shape, size, structure, and method of dehiscing to those of *Datura fastuosa*, except that the latter have fewer spines or sometimes are spineless and smooth.

11. The seeds of the two plants are the same in general appearance, but those of *Datura fastuosa* are thinner, flatter, rather darker, and smoother than the seeds of *Datura alba*.

12. In the longitudinal section of the seeds, cut in the plane parallel to the flattened surface, although the characteristic curvature of the embryo of *Datura alba* is similar to that of *Datura fastuosa*, that of the latter can be easily identified because the tips of the pair of cotyledons and the lower end of its radicle are closer than are those of the former, and sometimes they almost touch each other.

13. The microscopical structures of the seeds of the two plants are almost identical. The testa is their most important characteristic. It consists of radially and tangentially elongated, thick-walled, greatly lignified, and tangentially pitted cells. In the inner part of the testa there are layers of parenchyma and obliterated parenchyma cells. Between these cells and the epidermal cells of the endosperm the perisperm is found. The endosperm cells are more or less polygonal in outline and filled up with aleurone grains and some oil globules.

14. The calcium oxalate crystals are generally the same in appearance in both plants. In the midrib of *Datura fastuosa*, however, the sphenoidal microcrystals and the prismatic and rosette forms are more abundant than in the midrib of *Datura alba*.

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ILLUSTRATIONS

[All microscopic drawings by the author. The macroscopic drawings for Plates 1, 4, and 6 were made by Macario Ligaya, of the Bureau of Science. The photographs for Plate 5 were made by Jesus Redondo, of the Department of Botany, University of the Philippines.]

PLATE 1. DATURA ALBA NEES

- FIG. 1. A habit sketch of a portion of the plant. $\times \frac{1}{2}$.
 2. A full-grown leaf. $\times \frac{1}{2}$.
 3. The corolla split down one side and spread, showing the five epipetalous stamens. $\times \frac{1}{2}$.
 4. A stamen before dehiscing; *a*, ventral view; *b*, dorsal view. $\times 1\frac{1}{2}$.
 5a. Pollen grains as they appear when mounted dry. $\times 200$.
 5b. Pollen grains as they appear when mounted in water. $\times 200$.
 6. A pistil with a portion of the style removed; *c*, basal portion of calyx; *co*, basal portion of corolla; *ng*, nectary gland; *o*, ovary with sharp erect processes; *s*, basal part of style; *st*, stigma. $\times 2$.
 7. A transverse section from the upper part of an ovary, diagrammatic drawing. $\times 5$.
 8. A transverse section from the lower part of an ovary, diagrammatic drawing. $\times 5$.
 9. A mature fruit showing method of dehiscing. $\times \frac{1}{2}$.
 10. Mature seed, lateral view. $\times 2\frac{1}{2}$.
 11. Mature seed; *a*, ventral view; *b*, dorsal view. $\times 2\frac{1}{2}$.
 12. Diagrammatic drawing of a median longitudinal section of a seed, cut in the plane parallel to the flat surface; *sc*, seed coat; *e*, endosperm; *em*, embryo; *h*, hilum. $\times 4\frac{1}{2}$.
 13. Diagrammatic drawing of a transverse section of a seed, cut at right angles to the flat surface: *sc*, seed coat; *e*, endosperm; *ct*, cotyledons; *r*, radicle. $\times 4\frac{1}{2}$.
 14. A thin transverse section through the seed coat and endosperm; *t*, testa; *p*, parenchyma region; *op*, obliterated parenchyma region; *pe*, perisperm; *e*, endosperm. $\times 68$.
 15. A highly magnified drawing of an endosperm cell; *og*, oil globule; *a*, aleurone grains. $\times 280$.
 16. A small portion of the seed coat from a transverse section of the seed near the region of the flat surface. $\times 68$.
 17. A small portion of the seed coat from a transverse section of the seed corresponding to the corrugated region. $\times 68$.

PLATE 2. DATURA ALBA NEES

- FIG. 18. A group of isolated cells of the testa; *a-c*, cells from the corrugated region; *d-g*, cells from the region corresponding to the flat surface of the seed. $\times 68$.

- FIG. 19. A surface view of the cells of the testa, showing interlacing processes, *pr*. $\times 68$.
20. A thin tangential section of the testa from the convoluted region of the seed coat, showing the striated and double character of the cell walls. $\times 68$.
21. A cross section through the midrib; *ph*, phloëm; *cc*, crystal cell containing calcium oxalate crystal in rosette form; *cr*, sphenoidal microcrystal of calcium oxalate. $\times 68$.
22. Surface view of the upper epidermis. $\times 200$.
23. Surface view of the lower epidermis. $\times 200$.

PLATE 3. DATURA ALBA NEES

24. Surface view of the upper epidermis cleared with a dilute solution of chloral hydrate, showing striation of the cuticle. $\times 285$.
25. Surface view of the lower epidermis cleared with a dilute solution of chloral hydrate, showing striation of the cuticle. $\times 285$.
26. Surface view of the outer epidermis of the calyx. $\times 200$.
27. Surface view of the inner epidermis of the calyx. $\times 200$.
28. Surface view of the inner epidermis of the corolla. $\times 200$.
29. A glandular hair from the lower epidermis of the leaf. $\times 285$.
30. A glandular hair from the corolla with shriveled terminal head and thick-walled basal cells. $\times 200$.
31. A glandular hair from the corolla. $\times 200$.
32. Group of calcium oxalate crystals; *a*, *f*, *g*, *h*, from the midrib; *b*, *c*, *d*, *e*, *g*, from the blade. $\times 285$.

PLATE 4. DATURA FASTUOSA LINNÆUS

- FIG. 33. A habit sketch of a portion of the plant, showing a flower with triple corolla. $\times \frac{1}{2}$.
34. A mature leaf. $\times \frac{1}{2}$.
35. A flower with double corolla. $\times \frac{1}{2}$.
36. The corolla split down one side; *co*₁, outer corolla which is free from the inner ones; *co*₂, second corolla from outside; *co*₃, innermost, or third corolla; *ap*, appendagelike structures found between the second and the third corollas. $\times \frac{1}{2}$.
37. A portion of the dorsal part of the third corolla and a portion of the ventral part of the second corolla, showing the five linear, appendagelike structures between them. $\times \frac{1}{2}$.
38. Two views of a stamen before dehiscing; *a*, dorsal view; *b*, ventral view. $\times \frac{1}{2}$.
- 39*a*. Pollen grains as they appear when mounted dry. $\times 200$.
- 39*b*. Pollen grains when mounted in water. $\times 200$.
40. A pistil with a portion of the style removed; *c*, basal portion of calyx; *co*₁, *co*₂, *co*₃, basal portions of the corolla; *ng*, nectary gland; *o*, ovary with flat processes; *s*, basal part of style; *st*, stigma. $\times 2$.
41. Diagrammatic drawing of a transverse section from the upper part of an ovary. $\times 5$.
42. Diagrammatic drawing of a transverse section from the lower part of an ovary. $\times 5$.

- FIG. 43. Inner corolla of an abnormally borne corolla, split down one side and spread, showing the five epipetalous stamens with filaments provided with appendages. $\times \frac{1}{2}$.
44. Stamens from the specimens illustrated in fig. 43, drawn natural size; *a*, normal; *b-f*, with winglike structure. $\times 1$.
45. A fruit without spines, showing method of dehiscing. $\times \frac{1}{2}$.

PLATE 5. *DATURA FASTUOSA* LINNÆUS

- FIG. 46. A fruit with few and short spines.
47. An abnormally borne flower, showing the middle part of the inner corolla tube bent and protruding at the side of the outer corolla.
48. Three stages of abnormally borne corolla.
49. The flower; *a*, abnormal flower split down one side, showing the normal anthers and the united filaments with appendages, or winglike structures; *b*, an abnormal flower, in which the filaments are not united.
50. The flower; *a*, an abnormally borne flower, compared with *b*, a normally borne flower.

PLATE 6. *DATURA FASTUOSA* LINNÆUS

- FIG. 51. The seed; *a*, flat side of mature seed; *b*, dorsal side. $\times 2\frac{1}{2}$.
52. Diagrammatic drawing of a median longitudinal section of a seed, cut in the plane parallel to the flat surface; *sc*, seed coat; *e*, endosperm; *em*, embryo; *h*, hilum. $\times 4\frac{1}{2}$.
53. Diagrammatic drawing of a transverse section of a seed, cut at right angles to the flat surface; *sc*, seed coat; *e*, endosperm, *ct*, cotyledons; *r*, radicle. $\times 4\frac{1}{2}$.
54. A thin transverse section through the seed coat and endosperm; *t*, testa; *p*, parenchyma region; *op*, obliterated parenchyma region; *pe*, perisperm; *e*, endosperm. $\times 4\frac{1}{2}$.
55. A highly magnified drawing of an endosperm cell; *a*, aleurone grain. $\times 285$.
56. A small portion of the seed coat from a transverse section of the seed near the region of the flat surface. $\times 68$.
57. A small portion of the seed coat from a transverse section of the seed corresponding to the flat surface. $\times 68$.
58. A small portion of the seed coat from a transverse section of the seed corresponding to the corrugated region. $\times 68$.
59. Surface view of the cells of the testa, showing the interlacing outgrowths from the cells. $\times 68$.
60. A thin tangential section through the corrugated region of the seed coat, showing the striation and double character of the cell walls. $\times 68$.
61. A group of isolated cells of the testa; *a-d*, cells from the corrugated region; *e-h*, cells from the region corresponding to the flat surface of the seed. $\times 68$.
62. A cross section through the midrib; *ph*, phloëm; *cc*, crystal cell containing calcium oxalate crystals in rosette form; *cr*, calcium oxalate crystals in prismatic form; *crs*, sphenoidal microcrystals of calcium oxalate. $\times 68$.

PLATE 7. *DATURA FASTUOSA* LINNÆUS

- FIG. 63. Surface view of the upper epidermis of a leaf. $\times 200$.
64. Surface view of the lower epidermis of a leaf. $\times 200$.
65. Surface view of the upper epidermis of a leaf, cleared with a dilute solution of chloral hydrate, showing striation of the cuticle. $\times 285$.
66. Surface view of a leaf with the epidermis cleared with a dilute solution of chloral hydrate, showing striation of the cuticle. $\times 285$.
67. Surface view of the outer epidermis of calyx. $\times 200$.
68. Surface view of the inner epidermis of calyx, showing aborted stomata or young stomata. $\times 200$.
69. Surface view of the outer epidermis of the corolla. $\times 200$.
70. A glandular hair from the calyx. $\times 285$.
71. A glandular hair from the leaf. $\times 285$.
72. A glandular hair from the corolla. $\times 200$.
73. A glandular hair from the corolla. $\times 200$.
74. Group of calcium oxalate crystals; *b-f*, from blade; *a*, *g-m*, from midrib. $\times 285$.

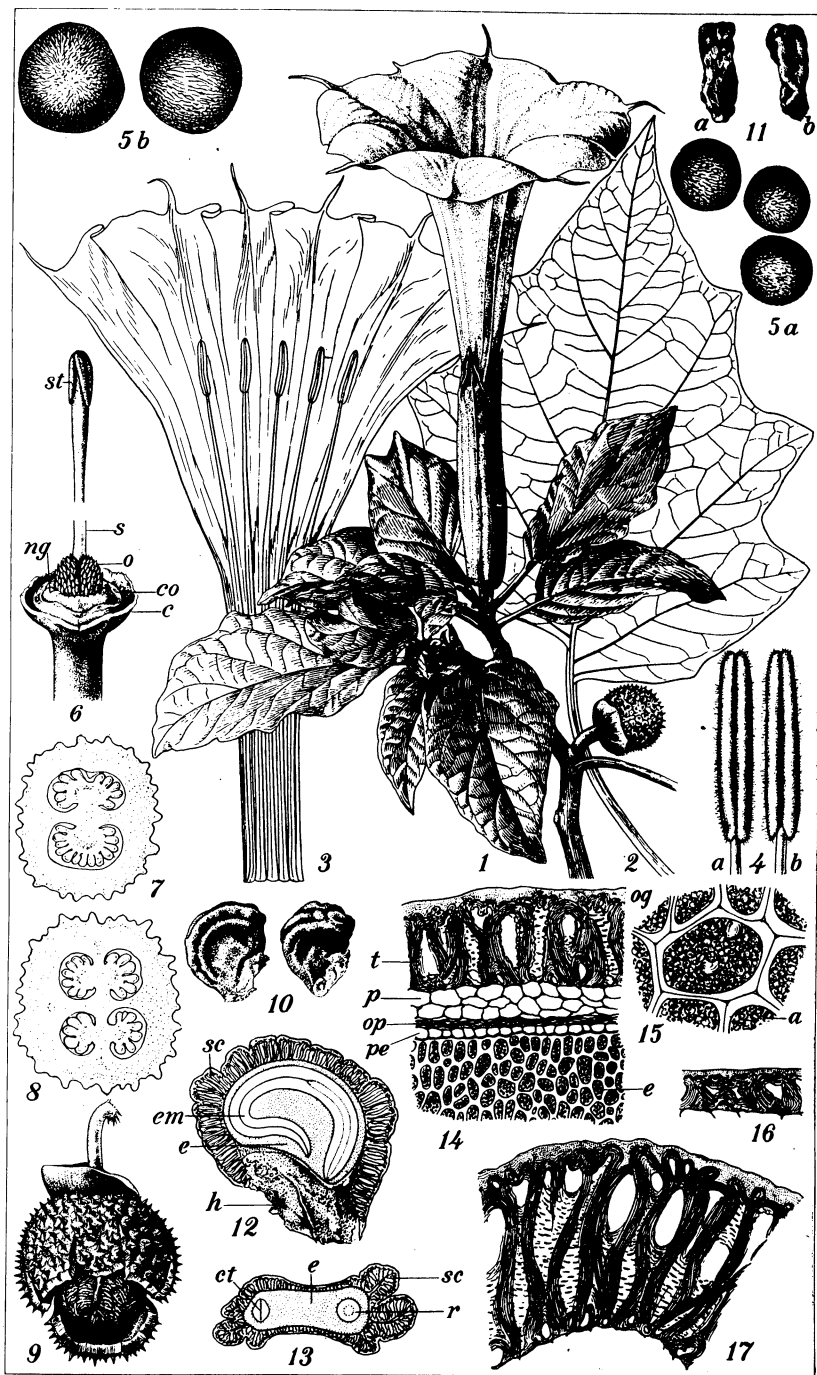


PLATE 1.

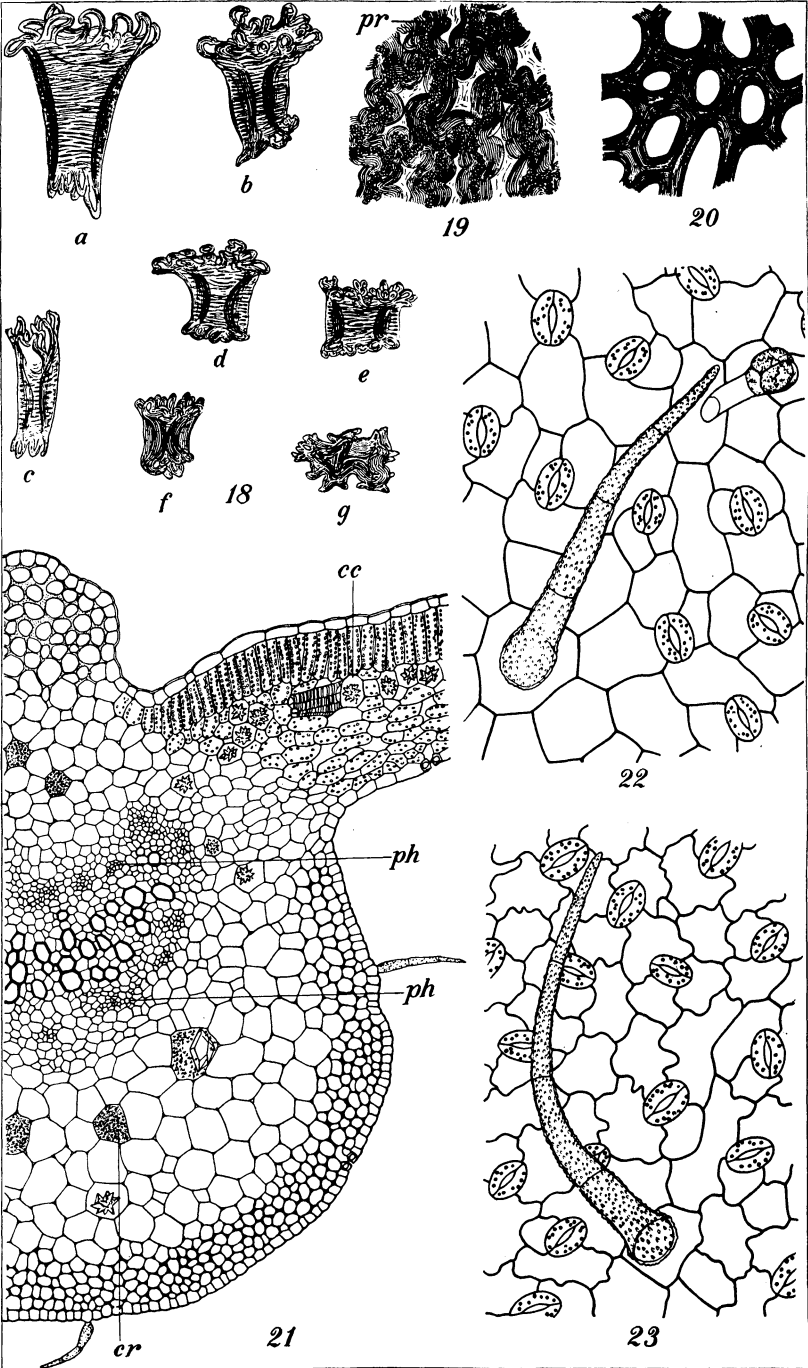


PLATE 2.

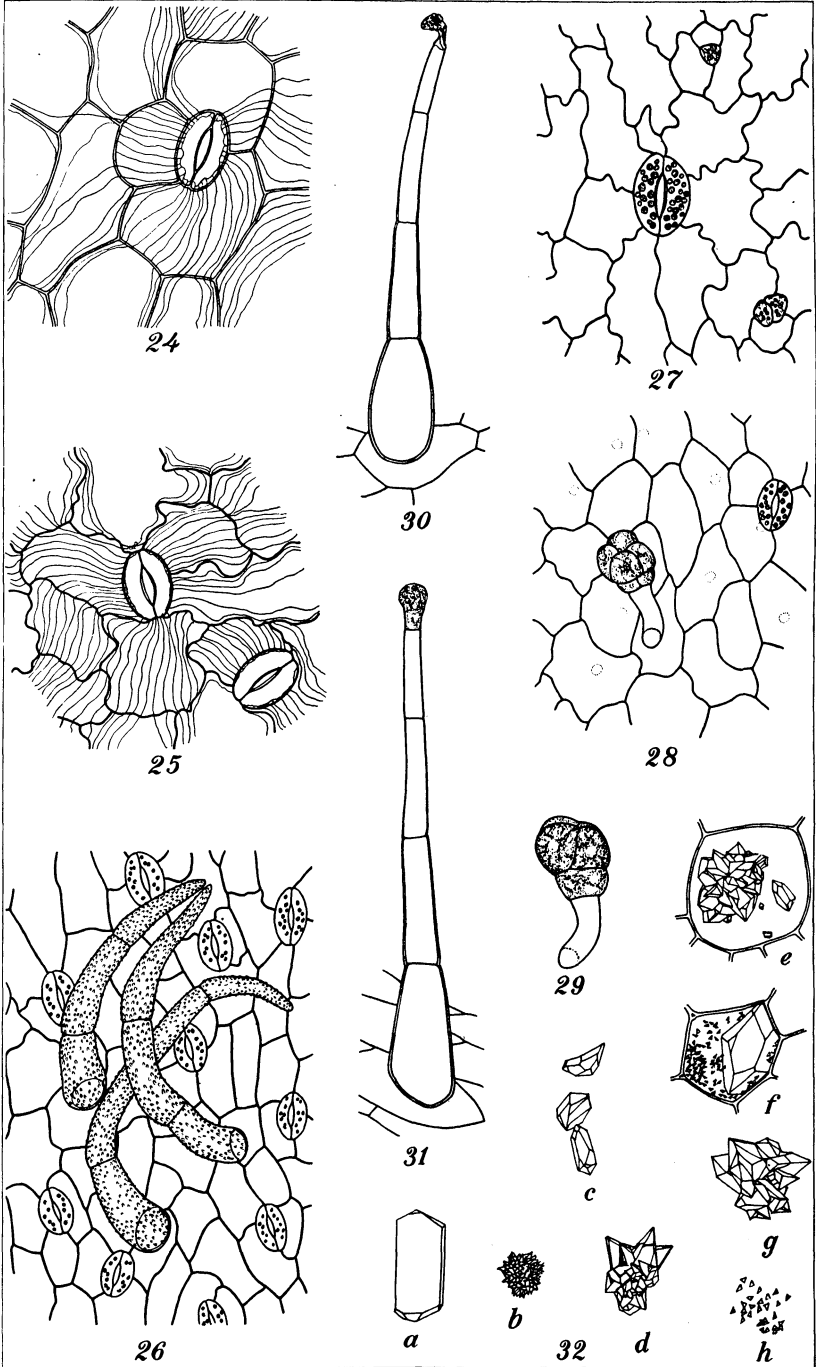


PLATE 3.



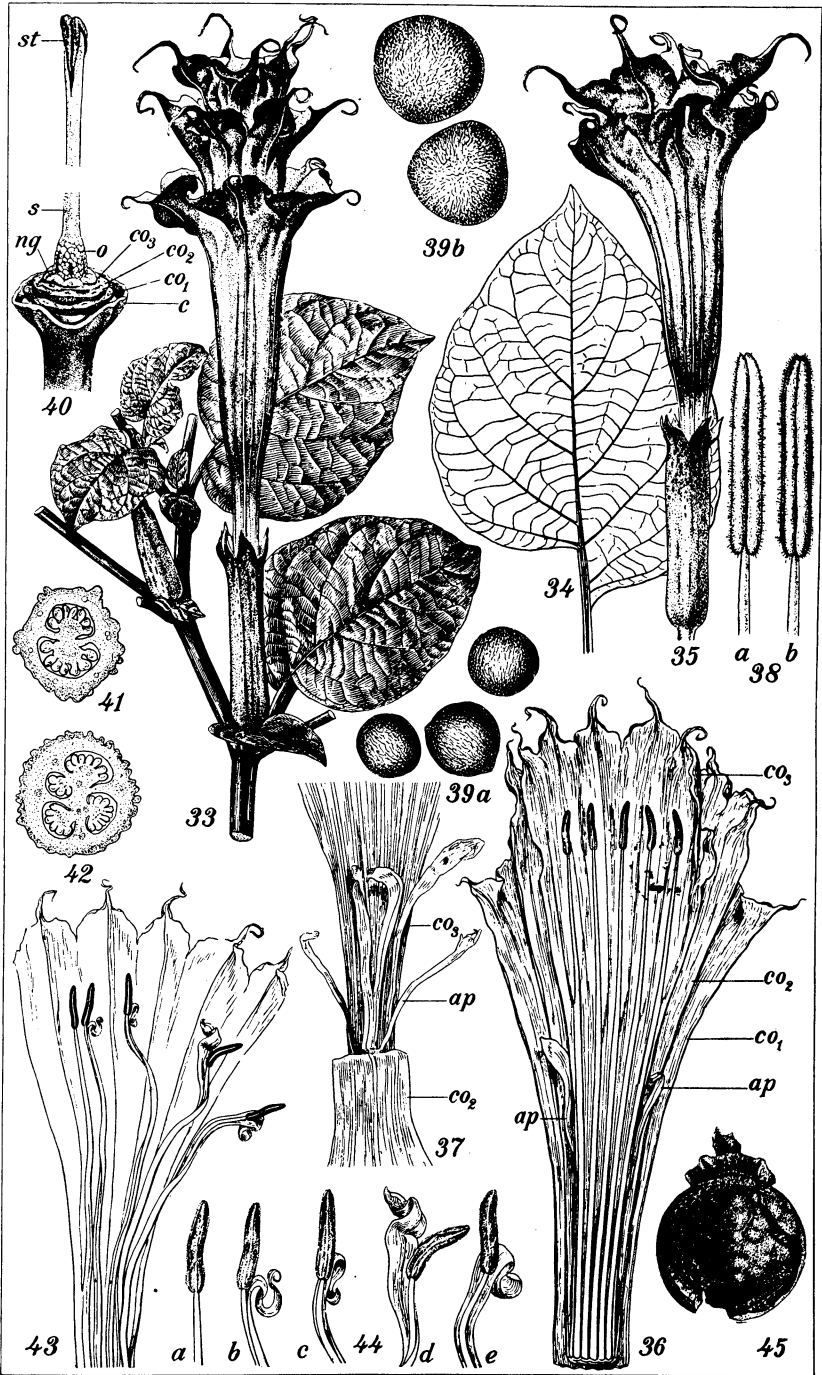


PLATE 4.



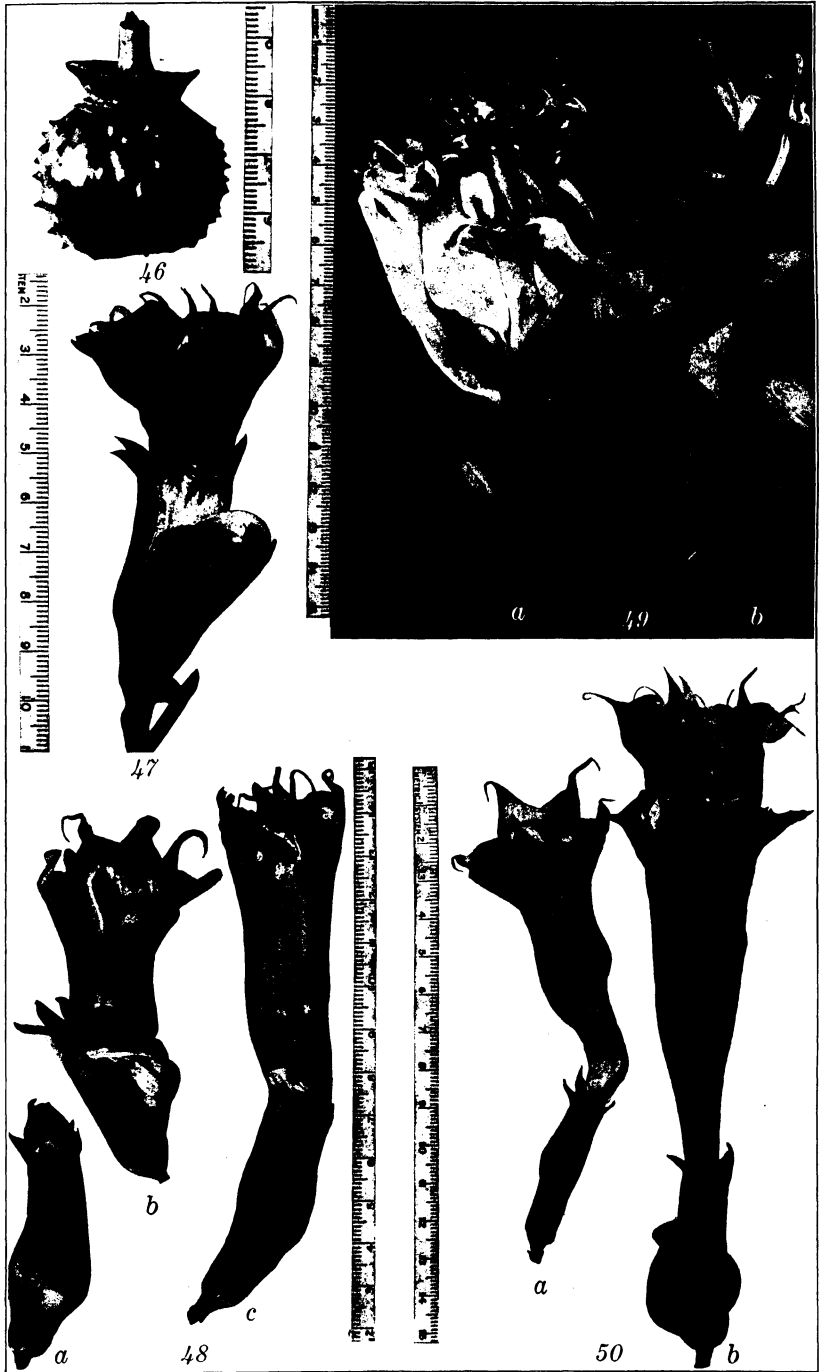


PLATE 5.



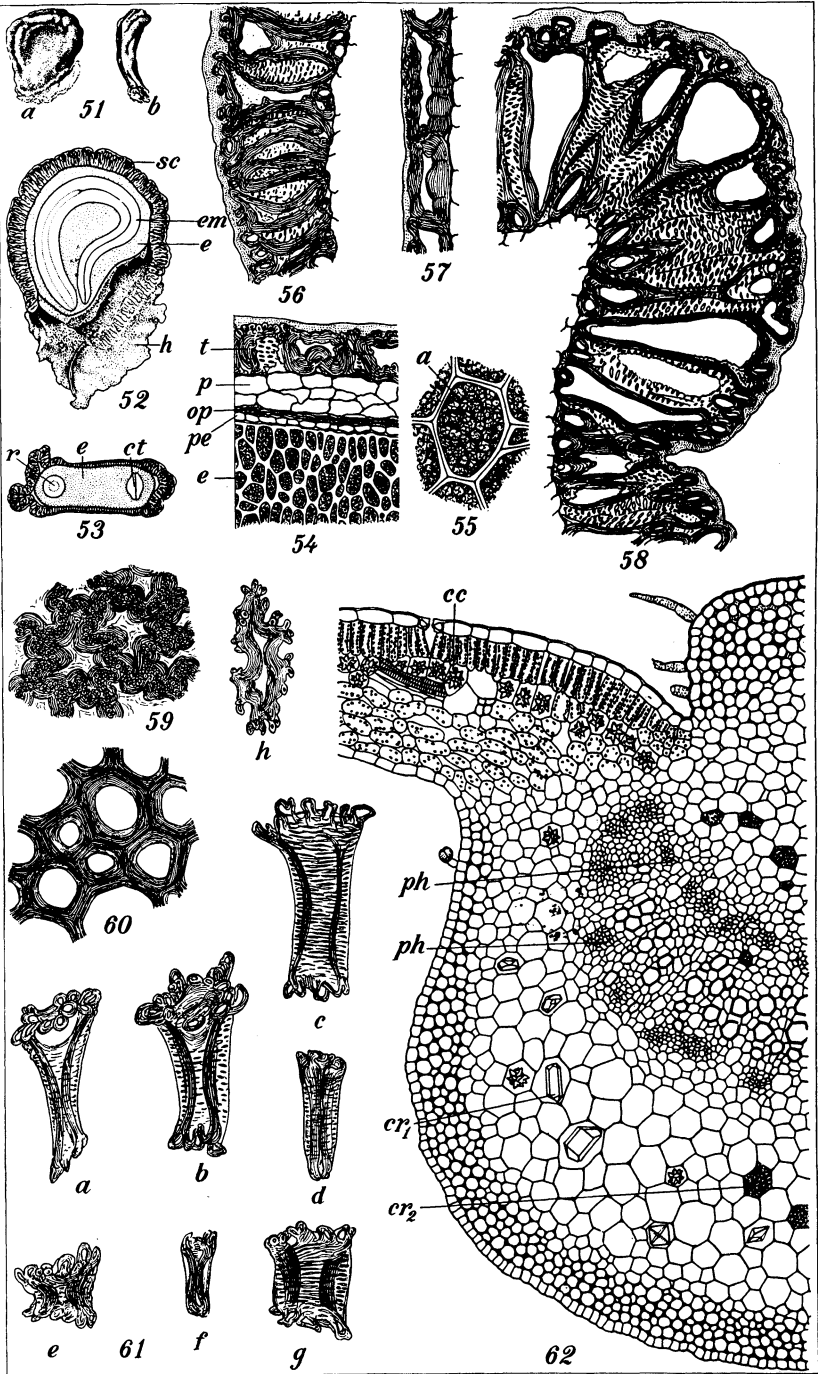


PLATE 6.



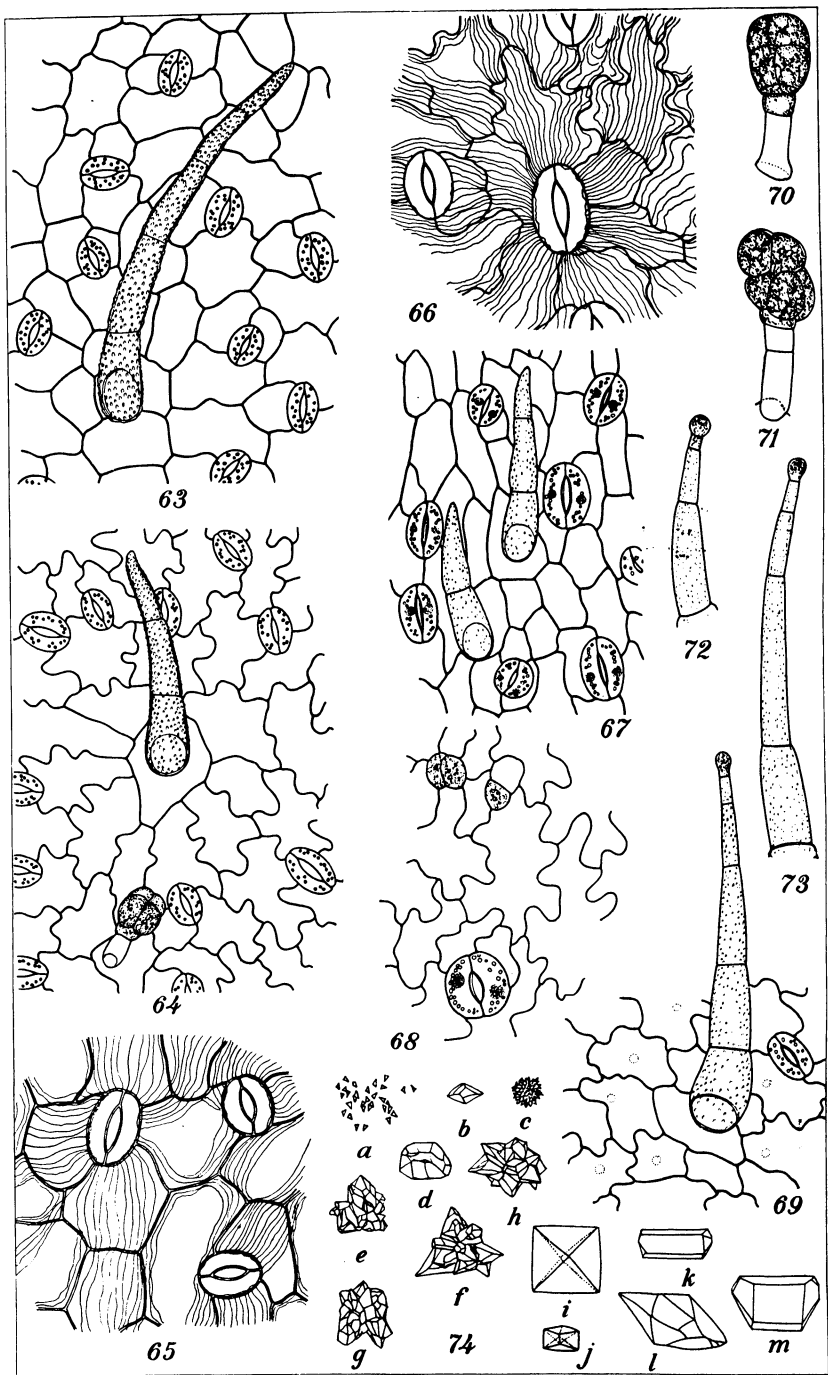


PLATE 7.



REDUCTION OF LINOLENIC AND LINOLIC BROMIDES AND REBROMINATION OF THE FREE ACIDS

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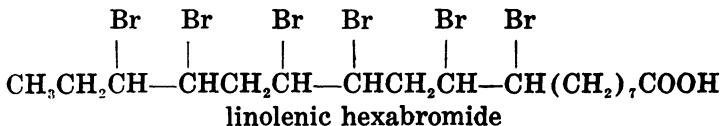
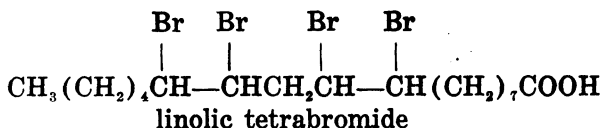
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ONE TEXT FIGURE

INTRODUCTION

The unsaturated glycerides of linolic and linolenic acids occur naturally in vegetable drying oils and are the principal substances that absorb oxygen from the air and cause the oil to dry. These glycerides and the corresponding unsaturated linolic and linolenic acids are therefore compounds of considerable commercial importance.

When linolic and linolenic acids are brominated they are converted into their bromo addition products; namely, linolic tetrabromide and linolenic hexabromide.



These bromination reactions may not, however, be as simple as the equations would seem to indicate.

Erdmann and Bedford¹ prepared linolenic hexabromide from linseed oil. When the hexabromide was reduced to the free linolenic acid and again brominated they obtained a mixture of the original crystallized hexabromide and some liquid bromide.

¹ Ber. Deut. Chem. Gesell. 42 (1909) 1328.

Takahashi² carried out some elaborate bromination experiments on the linolic acid obtained from soy-bean oil. He first prepared linolic tetrabromide (melting point, 114° C.) from soy-bean oil. This tetrabromide was reduced to the free linolic acid and again brominated. He obtained three types of bromo derivatives which he designated as follows:

1. Alpha linolic tetrabromide; crystals insoluble in petroleum ether; melting point, 113.5 to 114° C.
2. Beta linolic tetrabromide; crystals soluble in petroleum ether; melting point, 59 to 60° C.
3. Gamma linolic tetrabromide; liquid soluble in petroleum ether.

When each of these types was again reduced to the free linolic acid and brominated, each type gave the same three varieties of bromo derivatives. Each type, however, always gave more of its own kind.

The experiments of Erdmann and Bedford and the work of Takahashi indicate that either the elimination of bromine or the readdition of it gave molecular rearrangements which produced isomeric bromides.

Philippine lumbang oil is a drying oil used in making paints, varnishes, and similar products.³ It consists almost entirely of glycerides of the unsaturated acids, linolenic, linolic, and oleic.⁴ A recent investigation⁵ showed that, when the mixed acids of lumbang oil are brominated, linolenic hexabromide, four linolic tetrabromides (alpha, beta, delta, and gamma), and oleic dibromide are obtained. Gamma linolic tetrabromide and oleic dibromide are oils, whereas the other bromides are crystalline compounds.

The present investigation was undertaken to ascertain if the linolenic and linolic acids (from lumbang oil), when brominated, reduced, and again brominated, would give the same isomeric bromo derivatives as do the corresponding linolenic acid from linseed oil and the linolic acid from soy-bean oil. We also endeavored to learn if any molecular rearrangement occurs with lumbang compounds, and if such rearrangement is due to the removal of bromine from the bromo derivative or to the rebromination of the free acid.

Our results seem to show that the lumbang linolenic compounds have the same general characteristics as do the linseed

² Journ. Tokyo Chem. Soc. 40 (1919) 233.

³ West, A. P., and F. L. Smith, Bull. P. I. Bur. Forestry 24 (1923).

⁴ West, A. P., and Z. Montes, Philip. Journ. Sci. 18 (1921) 619.

⁵ Santiago, S., and A. P. West, Philip. Journ. Sci. 32 (1917) 41-52.

linolenic compounds. The lumbang linolic compounds, however, had a chemical behavior quite different from that of the soybean linolic compounds. Our experiments also indicate that molecular rearrangements occur with lumbang compounds. The rearrangement appears to take place during the removal of bromine from the bromo derivative and not during the bromination of the free acid.

EXPERIMENTAL PROCEDURE

Preparation of materials.—The linolenic hexabromide and linolic tetrabromides used in these experiments were prepared in accordance with the procedure adopted by Santiago and West⁶ in a recent investigation of lumbang compounds. The method of preparation was, in general, as follows: The lumbang oil was saponified with aldehyde-free alcoholic potassium hydroxide. The mixed potassium soaps thus obtained were converted in neutral solution into zinc soaps. The precipitated zinc soaps were removed by filtering and washed thoroughly with water to eliminate the lumbang odoriferous oil. The mixed zinc soaps were then treated with dilute sulphuric acid in an atmosphere of carbon dioxide and converted into the mixed acids.

Linolenic hexabromide.—The mixed acids were brominated in ether solution according to the procedure used by Imperial and West⁷ in preparing linolenic hexabromide. The ether solution of mixed acids was stirred mechanically by means of a hot-air motor and brominated at -10° C. The insoluble linolenic hexabromide was removed by filtering. After crystallizing from ethyl acetate and benzene the melting point of the hexabromide was 179.5 to 180.5° C. The bromine content was 63.02 per cent. Theory requires 63.32 per cent bromine.

Linolic tetrabromides.—The ethereal filtrate from the hexabromide was treated with sodium thiosulphate solution to remove the bromine, dehydrated with sodium sulphate, and distilled to eliminate the ether. The residue was treated with cold petroleum ether which precipitated a mixture of linolic tetrabromides. The crude solid tetrabromides were separated from the oily (gamma) tetrabromide and the oily oleic dibromide by filtering. The crude crystalline tetrabromides were washed with petroleum ether, after which they were crystallized from ethyl alcohol. Two crops of impure alpha linolic tetrabromide (melting point 110 to 113° C.) were obtained. The crude alpha tetrabromide

⁶ Philip. Journ. Sci. 32 (1927) 41-52.

⁷ Philip. Journ. Sci. 31 (1926) 441-449.

was washed again with petroleum ether and crystallized once from gasoline and several times from ethyl alcohol. After this further purification the melting point was 112.3 to 114.3° C. The bromine content was 53.73 per cent. Theory requires 53.33 per cent bromine.

When the filtrate from the second crop of the alpha compound was concentrated, by distilling off about a third of the alcohol, a red oily layer separated out at the bottom of the alcoholic solution. The red oil was separated from the supernatant alcoholic solution of the alpha compound. When shaken with a small quantity of cold ethyl alcohol a considerable portion of it gradually crystallized and was converted into silky crystals.

That portion of the red oil which did not crystallize gave a bromine content of 53.69 per cent and was thus shown by analysis to be a liquid linolic tetrabromide (gamma).

The silky crystals obtained from a portion of the red oil were crystallized from ethyl alcohol. The melting point was 59.6 to 60.6° C. The bromine content was 53.44 per cent. The silky crystals, as shown by Santiago and West, are a mixture of two substances—beta linolic tetrabromide and delta linolic tetrabromide.

The following bromo derivatives were thus prepared from lumbang oil and used as materials for this investigation:

Bromo derivatives.	Melting point. °C.
Linolenic hexabromide	179.5 to 180.5
Linolic tetrabromides:	
Alpha	112.3 to 114.3
Mixture beta and delta	59.6 to 60.6
Gamma	Liquid.

Reduction of linolenic hexabromide.—Linolenic hexabromide was reduced to the corresponding free linolenic acid according to the general procedure used by Erdmann and Bedford.⁸ The bromide was reduced with zinc filings in alcoholic solution. A part of the bromide was thus converted into an ester and the remainder into the zinc salt. Both the ester and the zinc salt were then changed to the free linolenic acid.

In carrying out these experiments 6 grams of hexabromide were treated with 250 cubic centimeters of alcohol and 15 grams of zinc filings. Three drops of alcoholic platinum chloride solution were then added, in accordance with the suggestion of

⁸ Ber. Deut. Chem. Gesell. 42 (1909) 1328.

Matthes and Boltze.⁹ The mixture was heated on a water bath (reflux) until the reduction was complete, which required about twenty-four hours. The zinc was removed by filtering through a covered funnel in an atmosphere of carbon dioxide, using an apparatus arranged according to the diagram (fig. 1). A half-

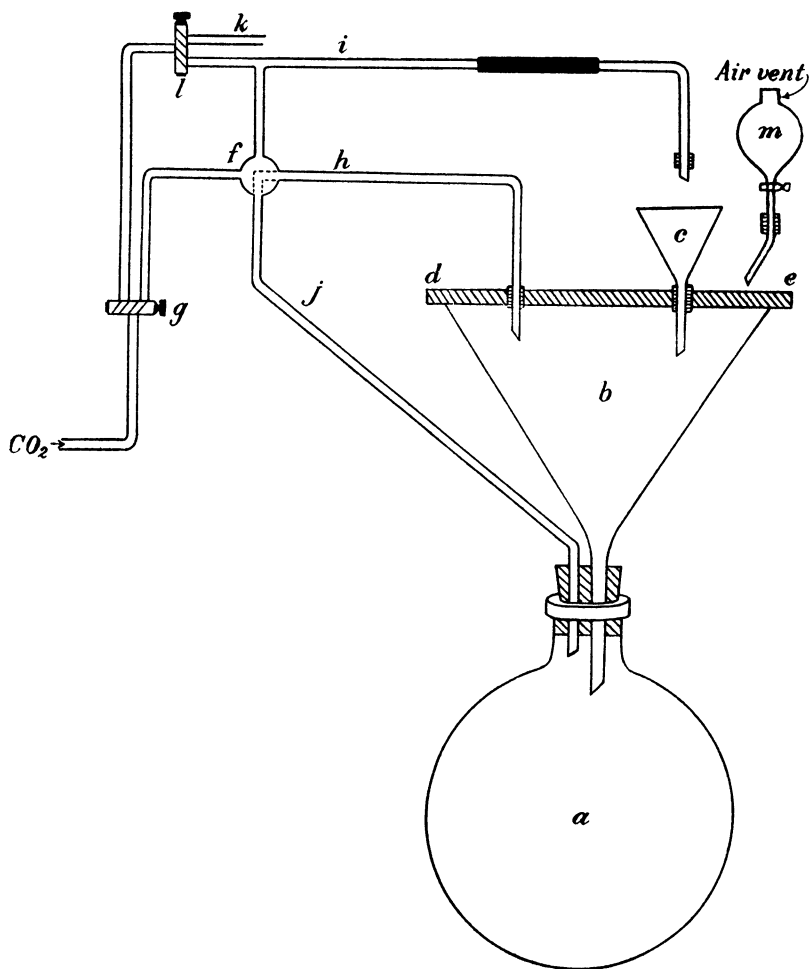


FIG. 1. Apparatus used for the reduction of bromo derivatives of unsaturated acids.

liter flask *a* was connected to a funnel *b*, containing filter paper. The funnel was covered with a glass plate *de*, containing two holes. Through one hole passed a funnel *c*. The tubes *h* and *j* were connected to the three-way stopcock *f*, which allowed the

⁹ Arch. d. Pharm. 250 (1912) 223.

carbon dioxide to flow into flask *a* and funnel *b*. The two-way stopcock *g* allowed the excess of carbon dioxide to escape into the air through the tube *k* when the pressure became too great, and also through the tube *i* when it was desirable to obtain a closed circuit in the apparatus through the stopcock *f*. By allowing carbon dioxide to enter the apparatus through the circuit *g, f, j*, the air was replaced by the carbon dioxide. The stopcock *f* was then adjusted so that the carbon dioxide flowed according to the circuit *a, j, f, h, b*.

The mixture of reduced bromide and zinc was poured through the funnel *c*, and filtered into the flask *a*, through the paper in the funnel *b*. Immediately after all the mixture was poured through the funnel *c*, the funnel *c* was removed and replaced by the separating funnel *m*. Carbon dioxide was then admitted through the circuit *g, l, i, m*. When all the mixture had filtered into flask *a*, the flask *a* was removed and connected to a condenser, and the mixture distilled in a current of carbon dioxide to eliminate the alcohol. During the distillation the glass plate *de* was removed and the filter paper containing the zinc taken out of the funnel *b*. The glass plate *de* was again placed over the funnel *b*.

When all the alcohol had been distilled out of the mixture in flask *a*, the flask was again connected to the funnel *b*. The carbon dioxide circuit was still the same as in the filtering operation. One hundred fifty cubic centimeters of hot water were then poured into the separating funnel *m*, at the top of the apparatus, and allowed to flow into the flask *a*, containing the mixture of ester and zinc salt which were precipitated. A solution of hot sulphuric acid (1 : 1) was then poured through the separating funnel *m*, into the flask *a*, which was shaken gently. The acid was added until the mixture in the flask had a decided acid reaction, as shown by the indicator methyl orange, previously added. After standing a short time the zinc salt was completely decomposed and the solution had a clear appearance.

A bath of ice water was then placed under flask *a*, and raised until the flask was completely immersed in the water. When the mixture in flask *a* had cooled to room temperature, about 50 cubic centimeters of ether were poured through the separating funnel *m*, at the top of the apparatus. The flask *a* was then disconnected and a large separating funnel connected to the apparatus in the position just previously occupied by flask *a*. The contents of flask *a* were then poured into a second separating funnel, previously filled with carbon dioxide, and the lower acid

layer was drawn off into a third separating funnel. The ether layer was then poured through the small separating funnel *m*, at the top of the apparatus, into the first large separating funnel at the bottom of the apparatus. The acid solution in the third separating funnel was then extracted three times with ether and the ether extracts were poured through the apparatus into the large separating funnel containing the first ether extract. Cold boiled distilled water was then poured through the top of the apparatus into the ether extract in the separating funnel at the bottom of the apparatus. The funnel was given a whirling motion in order to wash the ether extract, after which the aqueous solution was separated. The ether solution was thus washed several times with distilled water until free of acid. The ether solution was then drawn off into a half-liter balloon flask and distilled on a water bath (60° C.) in a current of carbon dioxide until the ether extract was reduced to a volume of about 50 cubic centimeters. The stopper, through which the carbon dioxide inlet tube passed, was then raised slightly and about 200 cubic centimeters of aldehyde-free alcohol were added to the ether extract. An alcoholic solution of potassium hydroxide, containing about one gram of potassium hydroxide, was poured into a separating funnel. The separating funnel was inserted into the balloon flask until the lower end was slightly below the surface of the ether extract. The potassium hydroxide solution was then allowed to flow into the ether extract. The mixture was then heated on a water bath (reflux) until the ester was completely saponified, which required about three and a half hours. The alcohol and ether were then removed by distilling in a current of carbon dioxide. The free organic acid was liberated with sulphuric acid and extracted with ether, as in the previous extraction. The combined ether extracts were dehydrated with sodium sulphate and filtered in an atmosphere of carbon dioxide into a liter flask.

Rebromination of linolenic acid.—The ether extract was diluted with ether to a volume of about 600 cubic centimeters and brominated according to the general procedure used by Imperial and West¹⁰ in preparing linolenic hexabromide. The ethereal solution was stirred mechanically by means of a hot-air motor and cooled to a temperature of —10° C. Carbon dioxide was passed into the flask above the surface of the liquid; the solution, in this atmosphere of carbon dioxide, was then treated

¹⁰ Philip. Journ. Sci. 31 (1926) 441–449.

with 3.5 cubic centimeters of bromine. After bromination the crystallized hexabromide was removed by filtering. The ethereal filtrate from the hexabromide was treated with sodium thio-sulphate solution to remove the excess bromine, after which it was dehydrated with sodium sulphate and the ether eliminated by distilling. The residue was a very light yellow oil which gradually turned somewhat dark. About 30 per cent of the material was lost in manipulation. Approximately 46.8 per cent of the reaction products consisted of crystallized hexabromide (melting point 180 to 182° C.) which gave a bromine content of 63.04 per cent. The liquid hexabromide, which analyzed 63.28 per cent bromine, constituted 53.2 per cent of the reaction products. The theoretical bromine content of linolenic hexabromide is 63.32 per cent.

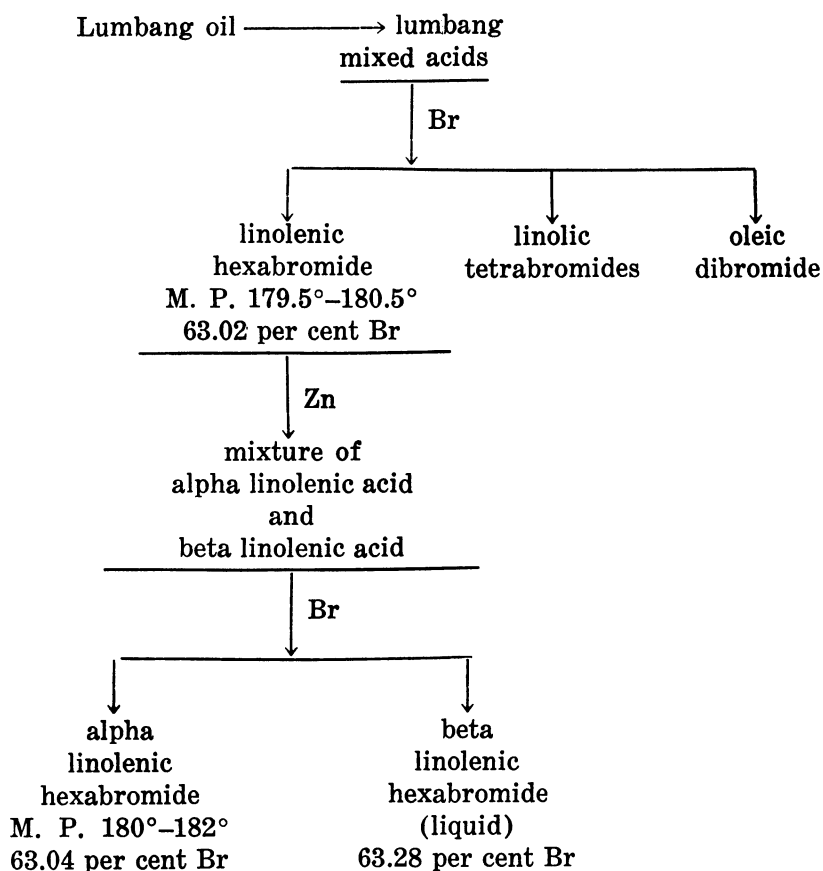
Results with linolenic compounds.—Our results with lumbang linolenic acid are quite similar to the results obtained by Erdmann and Bedford¹¹ with linseed linolenic acid. They found, when the crystallized linolenic hexabromide from linseed oil was reduced and the reaction product brominated, that a crystallized hexabromide and also a liquid bromide were obtained.

When the mixed acids of lumbang oil are brominated directly, no liquid linolenic hexabromide is obtained, but only the crystallized hexabromide. Evidence favoring this view is the fact that the liquid linolic tetrabromide obtained from the filtrate of the crystallized linolenic hexabromide was found, as will be shown later, to contain a hexabromide which on reduction and rebromination gave the same proportion of crystalline and liquid hexabromide as the original crystalline hexabromide gave when reduced and brominated. These results indicate that the hexabromide, which is contained in the liquid tetrabromide, is the ordinary crystalline hexabromide obtained only by brominating the one linolenic acid present in the lumbang mixed acids. The mixed acids of lumbang oil appear to contain only one linolenic acid, and when this acid is brominated only one hexabromide is obtained. When this crystallized hexabromide is reduced with zinc a molecular rearrangement seems to occur and two linolenic acids are obtained; namely, alpha and beta. Bromination of these mixed linolenic acids gives the crystallized alpha linolenic hexabromide and the liquid beta linolenic hexabromide.

¹¹ Ber. Deut. Chem. Gesell. 42 (1909) 1328.

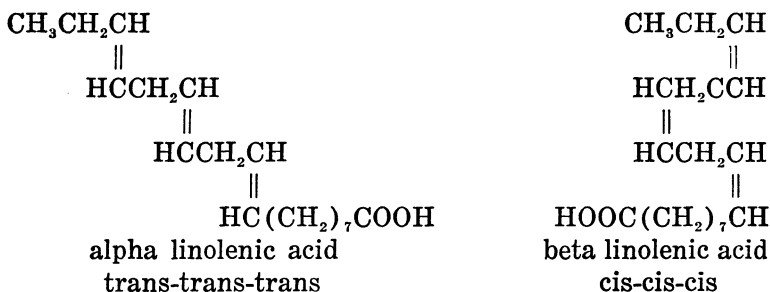
Our results seem to show that the molecular rearrangement occurs during the reduction of the bromide and not during the bromination of the free acid because, when the mixed lumbang-free acids are first brominated, only one linolenic hexabromide is obtained and that is the crystalline hexabromide. If isomeric linolenic hexabromides were obtained by brominating directly the mixed acids of lumbang oil, this would indicate that, possibly, a molecular rearrangement had occurred due to the bromination process, but such isomers are not obtained.

The results we obtained with lumbang linolenic compounds may be outlined as follows:



As shown by the above outline the crystallized linolenic hexabromide, when reduced, yields two linolenic acids; namely,

alpha and beta. These acids may, perhaps, be regarded as geometrical isomers. With such substances the isomer having the highest melting point is usually the trans form.¹² Since the alpha acid gives the crystalline hexabromide, while the beta acid yields the liquid hexabromide, the alpha acid may be a trans-trans-trans form and the beta acid the cis-cis-cis form, as represented by the following formulas:



Alpha linolic tetrabromide.—Alpha linolic tetrabromide (melting point 112.3 to 114.3° C.) was prepared from lumbang oil. It was then reduced to the free acid which was again brominated in accordance with the methods previously described for linolenic hexabromide. In these experiments 10 grams of the tetrabromide were treated with 250 cubic centimeters of alcohol and 25 grams of zinc filings. The mixture was heated on a water bath (reflux) for three and a half hours. The free acid was brominated by treating it with 1.8 cubic centimeters of bromine. About 34 per cent of the material was lost in manipulation. Approximately 48 per cent of the reaction product was crystallized alpha linolic tetrabromide (melting point 112.3 to 114.3° C.) which analyzed 53.16 per cent bromine. About 48 per cent was liquid tetrabromide (gamma) which analyzed 53.88 per cent bromine. The theoretical bromine content of linolic tetrabromide is 53.33 per cent. There was also obtained about 3 per cent of crystallized tetrabromide (melting point 109 to 112° C.) which was probably an impure form of the alpha compound. Beta and delta linolic tetrabromides were not obtained as reaction products.

Similar experiments carried out by Takahashi with the alpha linolic tetrabromide (melting point 114° C.) from soy-bean oil

¹² Stewart, A. W., Stereochemistry (1907) 175 and 177; Michael, A., Journ. für Prak. Chem. 52 (1895) 349.

showed that the alpha tetrabromide and also some beta (melting point 59 to 60° C.) and liquid gamma tetrabromide were obtained from the alpha compound.

Beta and delta linolic tetrabromides (silky crystals).—The silky crystals (melting point 59.6 to 60.6° C.), which consisted of a mixture of beta and delta tetrabromides, were reduced to the free linolic acids which were again brominated in accordance with the procedure used for the reduction and bromination of the alpha compound. About 38 per cent of the materials was lost in manipulation and the yield of reaction products was about 62 per cent. Approximately 30 per cent of the reaction products was crystallized alpha linolic tetrabromide (melting point 112.3 to 114.3° C.) which gave a bromine content of 53.05 per cent. The amount of liquid tetrabromide (gamma) contained in the reaction products was about 66 per cent. The gamma compound analyzed 53.37 per cent bromine. There was also obtained about 3.5 per cent of crystallized bromide (melting point 109 to 112° C.). This was probably an impure form of the alpha tetrabromide. Beta and delta linolic tetrabromides were not obtained as reaction products. This indicated that the tetrabromides were reduced completely to the free alpha and gamma linolic acids.

Beta linolic tetrabromide from soy-bean oil, when reduced and brominated by Takahashi, gave a mixture of crystallized alpha and beta tetrabromides and also some liquid gamma tetrabromide.

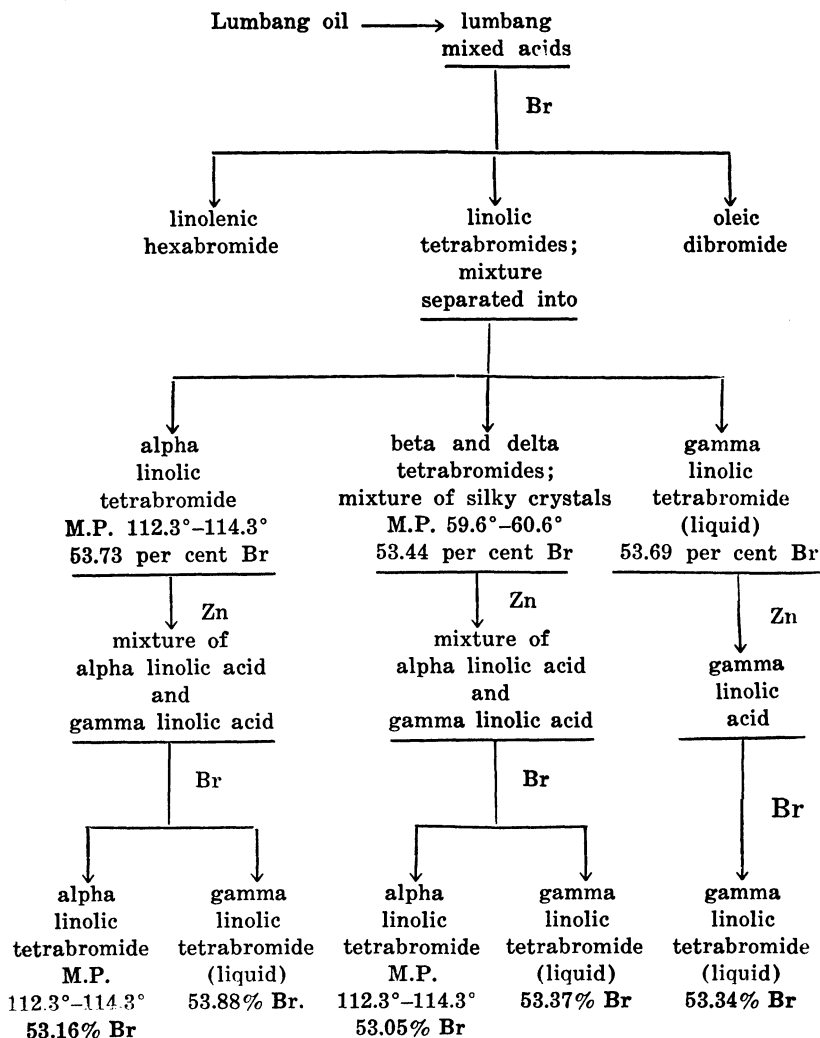
Gamma linolic tetrabromide.—The liquid gamma linolic tetrabromide was reduced and brominated under the same conditions as were the other tetrabromides. The reaction product consisted of 94.7 per cent of the original liquid gamma tetrabromide (bromine content, 53.34 per cent) and 5.3 per cent of linolenic hexabromides. Alpha, beta, and delta linolic tetrabromides were not obtained as reaction products. These hexabromide impurities consisted of 2.8 per cent of liquid hexabromide (bromine content, 62.82 per cent) and 2.5 per cent of crystalline hexabromide (melting point 180 to 184° C.). These hexabromide figures, when calculated to a basis of 100 per cent, gave 46.8 per cent crystalline hexabromide and 53.2 per cent liquid hexabromide. These figures are the same as those previously obtained by reduction and bromination of the crystalline hexabromide. The presence of these hexabromides in the liquid

gamma tetrabromide was probably due to the fact that the crystalline hexabromide, which is prepared by brominating directly the mixed acids of lumbang oil, is slightly soluble in alcohol, ether, and petroleum ether. In separating out the various linolic tetrabromide preparations the liquid gamma tetrabromide, which remains as a residue, is likely to contain substances, such as hexabromides, which may be present as impurities. If the gamma tetrabromide contains some crystalline hexabromide as impurity then when the impure gamma compound is reduced and brominated the crystalline hexabromide present as impurity will act as a pure crystalline hexabromide acts when reduced and brominated, and yield a mixture of crystalline and liquid hexabromides in the same proportions as are obtained from the crystalline hexabromide. As these results were actually obtained, the data indicate that when the mixed acids of lumbang oil are brominated the mixture of bromo derivatives contains only one hexabromide which is the crystalline linolenic hexabromide.

Results with linolic compounds.—Our experiments with lumbang linolic compounds gave results quite different from those obtained by Takahashi with the corresponding compounds made from soy-bean oil. Takahashi found that, when alpha linolic tetrabromide is reduced and the reaction product brominated, three types of bromides are obtained—alpha, beta, and gamma. Each type when again reduced and brominated gave the same three varieties (alpha, beta, and gamma) of bromo derivatives. It appears that Takahashi did not obtain from soy-bean oil a fourth variety of linolic tetrabromides corresponding to the delta tetrabromide which can be prepared from lumbang oil. Possibly his beta compound was really a mixture of beta and delta compounds and resembled our silky crystals which were a mixture of these substances.

In our experiments the alpha compound when reduced and brominated gave no beta or delta tetrabromides, but only the alpha and gamma tetrabromides. The beta and delta tetrabromides, reduced and brominated, also gave only the alpha and gamma tetrabromides. The gamma compound, treated in a similar manner, was converted back again into the same gamma compound.

Our results with lumbang linolic compounds may be outlined as follows:

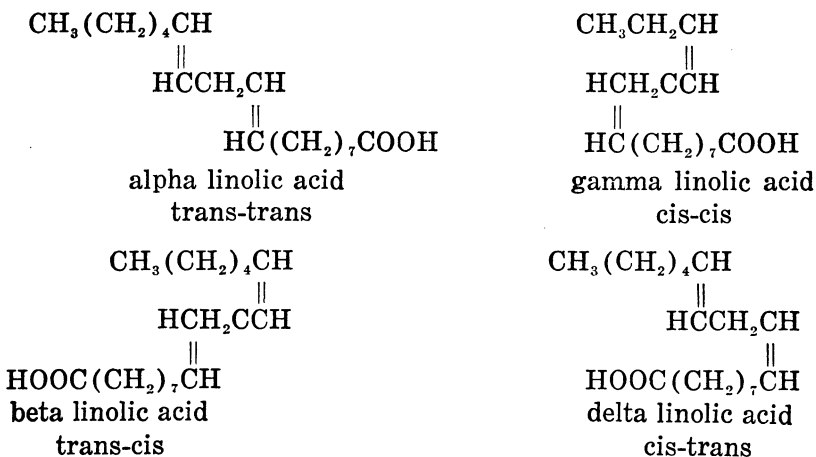


The beta and delta linolic tetrabromides are not obtained by reducing any tetrabromides and again brominating the resulting free linolic acids. The beta and delta linolic tetrabromides are prepared only by brominating directly the mixed acids of lum-

bang oil. It would thus appear that the mixed acids of lumbang oil contain in addition to the alpha and gamma linolic acids also two other linolic acids; namely, beta and delta. When brominated the beta acid yields the beta tetrabromide, while the delta acid gives the delta tetrabromide. Reduction of the beta and delta tetrabromides appears to give a molecular rearrangement and these substances are converted into a mixture of alpha and gamma linolic acids which, when again brominated, yield the corresponding alpha and gamma tetrabromides. As in the case of linolenic compounds, the molecular rearrangement appears to occur only during the reduction of the bromides and not during the bromination of the free acids.

Data obtained by Santiago and West¹³ in a recent investigation of lumbang oil indicated that, by brominating directly the mixed acids of lumbang, there were obtained a crystalline linolenic hexabromide, four linolic tetrabromides, and one oleic dibromide. These various bromides appeared to be derivatives of the corresponding acids contained as glycerides in the oil. The results of the present investigation seem to confirm the data obtained in this previous research.

The lumbang mixed acids appear to contain four linolic acids. These acids may, perhaps, be regarded as geometrical isomers. If they are named in accordance with the melting point of the tetrabromide derivative then these acids may perhaps be represented by the following formulas:



¹³ Philip. Journ. Sci. 32 (1927) 41-52.

SUMMARY

An apparatus and procedure have been described for the satisfactory reduction of bromo derivatives of long-chain unsaturated acids.

Lumbang linolenic compounds have the same general characteristics as do the linseed linolenic compounds. When the lumbang mixed acids are brominated directly, only one linolenic hexabromide (melting point 179.5 to 180.5° C.) is obtained. This indicates that, when the glycerides of lumbang oil are converted to acids, these mixed acids contain only one linolenic acid.

When lumbang linolenic hexabromide is reduced and the reaction product brominated two linolenic hexabromides are obtained—crystalline linolenic hexabromide (melting point 180 to 182° C.) and liquid hexabromide. These results seem to indicate that a molecular rearrangement occurs during the reduction of the hexabromide and not during the bromination of the free acid, because bromination of the mixed lumbang acids gives only the crystalline linolenic hexabromide.

Toward reduction and rebromination the behavior of lumbang linolic compounds is somewhat different from that of the soy-bean linolic compounds. When alpha linolic tetrabromide from soy-bean oil is reduced and the reaction product (free acid) again brominated, three types of bromides are obtained; namely, alpha, beta, and gamma. When the lumbang alpha linolic tetrabromide is reduced and rebrominated the alpha and gamma linolic tetrabromides are the only products obtained. Reduction and rebromination of the lumbang beta and delta tetrabromides also give a mixture of alpha and gamma tetrabromides. The gamma compound treated in a similar manner gives only the same gamma compound.

Beta and delta linolic tetrabromides are prepared only by brominating directly the mixed acids of lumbang oil. Reduction of the beta and delta tetrabromides appears to give a molecular rearrangement and these substances are converted into a mixture of alpha and gamma linolic acids which, when brominated, yield the corresponding alpha and gamma tetrabromides. As in the case of linolenic compounds, the molecular rearrangement appears to take place only during the reduction of the bromides, and not during the bromination of the free acids.

Data obtained in a recent investigation indicated that by brominating directly the mixed acids of lumbang oil a crystalline

linolenic hexabromide, four linolic tetrabromides, and one oleic dibromide are obtained. These various bromides appeared to be derivatives of the corresponding acids contained as glycerides in the oil. The results of the present investigation seem to confirm the data obtained in this previous research.

The lumbang mixed acids appear to contain four linolic acids. These acids may, perhaps, be regarded as geometrical isomers and distinguished according to the melting point of their bromo derivatives as follows:

Alpha linolic acid (trans-trans).

Beta linolic acid (trans-cis).

Delta linolic acid (cis-trans).

Gamma linolic acid (cis-cis).

ILLUSTRATION

TEXT FIGURE

FIG. 1. Apparatus used for the reduction of bromo derivatives of unsaturated acids.

A MODIFIED COMBUSTION METHOD FOR THE DETERMINATION OF BROMINE IN ORGANIC COMPOUNDS

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TWO TEXT FIGURES

The Carius method is the usual standard method employed for determining halogens in organic compounds. Although the Carius method usually gives good results it is rather slow and laborious. Several methods, quicker and less troublesome than the Carius, have been suggested. These shorter methods do not always give really accurate results with all classes of halogen compounds. Reliable results may often be obtained with chlorine compounds, but not with bromine compounds.

In this paper is described a modification of the combustion method. This modification applies particularly to the determination of bromine in organic compounds and consists, essentially, in heating the substance and oxidizing it in a current of oxygen. The resulting gases are passed through a heated tube containing a platinum contact, a layer of asbestos, and another platinum contact. The gases are then passed into an absorption solution containing sodium carbonate, to which a small quantity of sodium sulphite has been added. When the combustion is finished and the substance is entirely decomposed, the absorption solution is heated with a small quantity of hydrogen peroxide to oxidize the sulphite to sulphate. The solution is then acidified with nitric acid and treated with an excess of standard silver nitrate (0.1 N). The mixture is filtered with the aid of suction. The excess silver nitrate is then titrated with a tenth normal solution of thiocyanate, using ferric alum as an indicator.

The results obtained in this investigation indicate that the bromine content of ring compounds as well as of long-chain compounds may be determined fairly accurately by this modified combustion method.

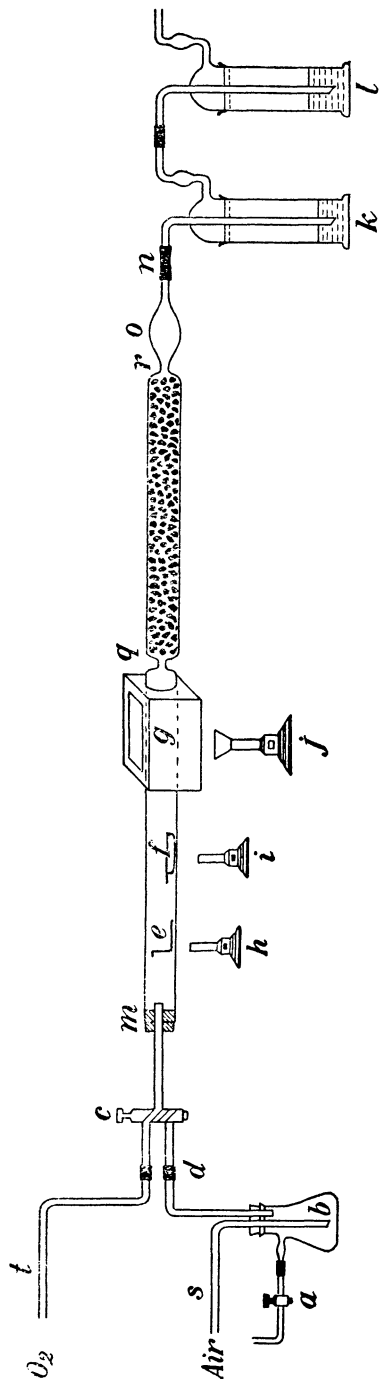


FIG. 1. Apparatus for the determination of bromine in organic compounds.

EXPERIMENTAL PROCEDURE

Apparatus.—The apparatus used for this method of bromine analysis was arranged according to the diagram given in fig. 1. A pyrex glass combustion tube mn (88 centimeters in length and 2.5 centimeters in diameter) was divided into two parts, mq and qn , by heating in a flame and making a constriction at the point q large enough to admit glass beads of the usual size. The tube was then heated near the absorption end n , and drawn out into the trap o . The constriction at r was made sufficiently small so that no glass beads could pass through into the trap o . This arrangement of the combustion tube was similar to that used by Pregl and Fyfe.¹ The lengths of the various parts of the tube were as follows: The length mq was 36 centimeters; qr , 33; and rn , 14. The absorption end n was drawn out somewhat so that it could be inserted into the exit end of a Drechsel wash bottle somewhat like the fit of a ground-glass stopper.

The absorption section qr of the tube was filled with glass beads. These were saturated with sodium carbonate solution, according to a procedure

¹ Quantitative Organic Micro Analysis (1924) 104.

to be described later. The wash bottles *k* and *l* contained a solution of sodium carbonate and sodium sulphite.

A portion, *g*, of the tube, about 20 centimeters from the combustion end *m*, was inclosed in an asbestos box.² The inside dimensions of the box were 13 centimeters long, 7.5 centimeters wide, and 8 centimeters high. The bottom of the asbestos box was perforated with a large hole, so that the combustion tube which passed through the box could be heated easily by the flame from a Terril fishtail burner. The hole in the bottom of the box was 11 centimeters long and 4 centimeters wide. There was also an opening in the top of the box, 10.5 centimeters long and 3.5 centimeters wide; it was covered with an asbestos lid. That portion of the tube inclosed in the asbestos box was wrapped with copper gauze so that when the tube was heated the heat would be somewhat evenly distributed over the entire surface of the tube.

The portion *g* of the combustion tube inside the asbestos box contained a round cylindrical basket made of platinum gauze. A special diagram of this section of the combustion tube is given in fig. 2, where *z* represents the platinum basket and *x* and *y* are platinum contacts. The platinum contacts were made of platinum foil and shaped somewhat like the letter W, with the ends bent over. The width was slightly less than the diameter of the combustion tube.

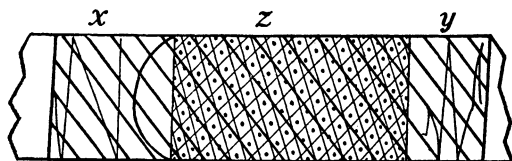


FIG. 2. Section of tube in asbestos box.

The length of the cylindrical basket was 7 centimeters and the diameter slightly smaller than the bore of the combustion tube. The basket was laced and bound with platinum wire and had a platinum wire handle so that it could be removed easily from the tube. The basket contained asbestos previously ignited. The asbestos sufficiently retarded the passage of volatile substances for them to be cracked and oxidized com-

² Meulen, H. Ter., *Recueil Des Travaux Chimiques des Pays-Bas* 43 (1924) 643; Smith, F. L., and A. P. West, *Philip. Journ. Sci.* 31 (1926) 265.

pletely.³ This was necessary, particularly with substances that sublimed or distilled through the tube.

The porcelain boat *f* contained the substance to be analyzed.

The platinum foil *e*, 3.4 centimeters in length, was bent in the middle to the shape of the letter L. This preceded the boat and served as an oxygen baffle and preheater. Should the sample explode and send volatile products back toward the cool end *m* of the combustion tube, the hot preheater *e* would tend to send the vapors back to the hot part *g* of the tube containing the platinum basket. The preheater also tends to make the combustion complete by dispersing the entering oxygen gas.

The tube *t* served to admit oxygen to the apparatus through the two-way stopcock *c*, while the tube *s* admitted air. The flask *b* was an attachment to adjust or equalize the pressure.

Reagents.—All reagents used in this work were especially purified and tested for halogens. All solutions used were free from suspended particles. The distilled water used was redistilled until tests showed complete absence of halogens. The saturated solution of sodium carbonate free of halogens was prepared from sodium bicarbonate and made exactly according to the directions given by Pregl and Fyleman.⁴ The sodium bisulphite solution free of halogens was prepared by treating sodium carbonate solution with sulphur dioxide according to the procedure given by Pregl and Fyleman.⁵ The nitric acid free of halogens⁶ was prepared by distilling the acid over silver nitrate in a current of carbon dioxide. The acid was then boiled until free of oxide fumes and water white in color. The iron alum indicator, tenth normal silver nitrate, and tenth normal thiocyanate solutions were all made according to procedures given by Sutton.⁷ The hydrogen peroxide used was the best grade of Merks. The asbestos was the usual chemically pure ignited asbestos. It was washed thoroughly with nitric acid and distilled water until free of halogens and again ignited. The oxygen employed in these combustion experiments was electrolytic oxygen manufactured by the Philippine Acetylene Company. It

³ Smith, F. L., and A. P. West, *Philip. Journ. Sci.* 31 (1926) 265.

⁴ Quantitative Organic Micro Analysis (1924) 110.

⁵ *Op. cit.* 111.

⁶ Sutton, S., *Volumetric Analysis*, 2d ed. (1924) 152; Pregl, F., and E. Fyleman, *Quantitative Organic Micro Analysis* (1924) 110.

⁷ *Volumetric Analysis*, 2d ed. (1924) 150, 151.

was purified by passing through a Drechsel wash bottle containing concentrated sulphuric acid and through three cylinders containing soda lime.

Analysis.—In carrying out this method of bromine analysis the apparatus was arranged in accordance with the diagram given in fig. 1. The apparatus was then taken apart temporarily and 1.5 cubic centimeters of saturated sodium carbonate solution were poured into the Drechsel wash bottle *l*, and 2 cubic centimeters of the same solution were poured into the wash bottle *k*. Three drops of sulphite solution were poured into each of the Drechsel wash bottles *l* and *k*. Distilled water (about 40 cubic centimeters) was then added to each wash bottle until the surface of the solution in the bottle was about 3 centimeters above the end of the inlet tube.

The combustion tube *mn* was held in a vertical position with the part *qn* below and the part *mq* above. The interior tube of a Liebig condenser was then inserted into the upper end *mq* of the combustion tube and lowered down to the constriction *q*. The lower end *n* of the combustion tube was closed by holding a finger over the outlet. Saturated sodium carbonate solution was poured through the interior Liebig tube until the absorption space *qr* containing the glass beads was filled with the carbonate solution. By introducing the carbonate solution in this manner the part *mq* of the combustion tube is not moistened with carbonate solution. The finger was removed from the outlet and the carbonate solution allowed to drain out. The tube was filled and drained twice more in the same manner. The Liebig condenser tube was removed and the combustion tube again connected to the Drechsel wash bottles, care being taken that no carbonate solution dropped into the section *mq* of the combustion tube.

The first platinum contact was inserted into the opening *m* of the combustion tube and pushed back near the constriction *q*, in that part of the tube covered by the asbestos box. The platinum basket containing the asbestos was placed in the tube next to the first contact. The second contact was placed immediately behind the platinum basket.

The porcelain boat containing the weighed sample was next placed in the combustion tube, about 4 centimeters from the asbestos box. The weight of sample used varied from about 0.0150 gram to 0.0390 gram, depending upon the bromine content of the particular sample. It is not advisable to use large

samples as they tend to explode and produce carbonaceous deposits which must be burned out in a current of oxygen. Volatile liquids were weighed as usual in sealed tubes.

The platinum foil *e* (baffle) was next inserted in the combustion tube and placed about 6 centimeters from the oxygen inlet. The combustion tube was then connected to the oxygen inlet.

When the combustion tube containing the weighed sample was arranged properly, a steady stream of oxygen was allowed to flow through the tube and the solutions in the Drechsel wash bottles. The rate of flow was regulated so that each minute about 60 to 90 bubbles of gas issued from the solutions in the Drechsel wash bottles.

The top of the asbestos box was removed temporarily; the Terril fishtail burner *j* under the asbestos box was lighted, and the tube heated with a low flame until the part *mq* was dry and rather warm. The lid was again placed on top of the asbestos box. The flame under the box was gradually increased until the platinum contacts were heated to low redness.⁸ A small, though rather intense flame *h* was placed under the baffle contact *e*, which was heated to a dull red color. The sample was then heated with a small flame *i*, and when it was entirely carbonized the temperature was increased until combustion was complete and no residue remained in the porcelain boat or, perhaps, only a small quantity of white ash. With some substances which do not oxidize readily it is advisable during the combustion to hold a piece of asbestos board or wire gauze above that part of the tube containing the boat. The temperature is thus increased sufficiently to produce complete combustion.

When the combustion was completed the flame under the porcelain boat was first extinguished and after about five minutes the flames under the asbestos box and the baffle contact were also extinguished. The lid of the asbestos box was removed and the tube allowed to cool. It requires usually about fifteen minutes to complete the combustion and about thirty minutes to cool the tube. When the tube had cooled to room temperature the flow of oxygen was discontinued. The safety stopcock *a* was opened and the Drechsel wash bottles and combustion tube disconnected. The products of the combustion

⁸ Pregl, F., and E. Fyleman, *Quantitative Organic Micro Analysis* (1924) 111.

reaction were absorbed mostly by the solution in the combustion tube *qn* and the solution in the Drechsel wash bottle *k*. The porcelain boat, platinum contacts, and basket were removed from the combustion tube. The filling tube (interior tube of a Liebig condenser) was inserted in the upper end *mq* of the combustion tube and lowered down to the constriction *q*. The solution in the Drechsel bottle *l* was then poured through the filling tube into the combustion tube and then into a 400-cubic-centimeter beaker. To this solution were added the contents of the Drechsel wash bottle *k*, and also the wash waters obtained by washing (as usual) the combustion tube and Drechsel bottles with distilled water. As the amount of wash water used was not excessive the final volume of the solution was about 200 cubic centimeters, which is an appropriate amount.

The solution was then treated with eight drops of hydrogen peroxide and heated ten minutes on a water bath. It was cooled in ice water, and made neutral to litmus with nitric acid. An excess of nitric acid (2 cubic centimeters) was added, after which 4 cubic centimeters of silver nitrate (0.1 *N*) were added slowly. The mixture was filtered immediately through a Gooch crucible and the precipitated silver bromide washed with a 1 per cent solution of nitric acid. The filtrate was transferred to an 800-cubic-centimeter beaker and to it were added 5 cubic centimeters of nitric acid (free of halogens) and 5 cubic centimeters of iron alum indicator, which was acidulated slightly with halogen-free nitric acid. The solution was titrated⁹ immediately with thiocyanate solution (0.1 *N*). The first appearance of a pinkish brown color was taken as the end point. In making this titration it is advisable to use a 10-cubic-centimeter burette graduated to $\frac{1}{20}$ of a cubic centimeter. A meniscus reader is also advantageous. The addition of silver nitrate and the titration should be done at room temperature.

RESULTS

In Table 1 is given a list of compounds analyzed by this modified combustion method. As shown by the data, the percentage of bromine as determined by analysis agrees rather closely with the calculated theoretical percentage of bromine.

This method seems to have several desirable features. As it requires only about two hours to make an analysis, the method

⁹ Sutton, S., *Volumetric Analysis*, 2d ed. (1924) 184.

is rather rapid. When the apparatus has once been assembled no special extra equipment, such as a microbalance, is required.

The results seem to indicate that this is a rather satisfactory method.

TABLE 1.—*Determination of bromine by a modified combustion method.*

Compound.	Bromine.	
	Found.	Theoretical.
	<i>Per cent.</i>	<i>Per cent.</i>
Linolenic hexabromides:		
Alpha.....	63.02	63.32
Beta (liquid).....	63.28	63.32
Linolic tetrabromides:		
Alpha.....	53.32	53.33
Beta.....	53.16	53.33
Gamma (liquid).....	53.37	53.33
Delta.....	53.28	53.33
Brombenzene (liquid).....	50.47	50.92
Bromoform (liquid).....	94.89	94.85
Dibromanthracene.....	47.60	47.58
Tribromaniline.....	72.65	72.70
Ethylene bromide (liquid).....	85.03	85.08
Dibrom chaulmoogramide.....	36.37	36.40
Dibrom chaulmoogra- <i>p</i> -toluide.....	30.13	30.21
Potassium salt of alpha linolic tetrabromide.....	50.10	50.13

SUMMARY

A modified combustion method for the determination of bromine in organic compounds has been described. The modification consists principally in using a platinum baffle and also a platinum basket containing asbestos fiber. The passage of a volatile substance through the asbestos fiber is retarded sufficiently for the substance to be cracked and decomposed completely, so that all the bromine is liberated before entering the carbonate absorption solution.

The essential features of this method are rapidity and ease of manipulation.

The method appears to give accurate results with both ring and long-chain compounds.

ILLUSTRATIONS

TEXT FIGURES

- FIG. 1. Apparatus for the determination of bromine in organic compounds.
2. Section of tube in asbestos box.

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VITAL CAPACITY AND PHYSICAL STANDARDS OF STUDENTS OF THE UNIVERSITY OF THE PHILIPPINES

By JUAN C. NAÑAGAS

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WITH THE ASSISTANCE OF

LEON C. SANTIAGO

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THREE TEXT FIGURES

Knowledge of a definite normal standard for each essential and fundamental physical measurement of any race of people is indispensable in the study of divers problems pertaining to individual or collective human development and for the correct determination of all other standards, physical, psychical, or otherwise. Physical standards are of basic need for a right understanding and solution of the material fitness and human efficiency of the different social components of a people and race. They are necessary for the correct interpretation of the future possibilities and degree of probabilities of the race. Standards are essential for the determination of appropriate measures for physical training as well as for the academic adaptation of the youth of a country. In brief, standards are the essential working basis for the study of many highly important problems pertaining to the education, health, efficiency, and wealth of a people.

Various demands of greater or lesser practical importance and usefulness are urgently made upon those of us who are expected to study and pass upon the parity of the Filipino race with the people of other regions. These demands range from the simple question of dimensions and physical features to that of the most complicated mental and psychical qualities and characteristics of Filipinos. They are encountered every day in science, in commerce, in education and, in fact, in all endeavors and enterprises touching on the line of modern activities and progress. It is to be regretted that a large amount of

qualifying data and conclusions on standards has been propagated and even accepted at the present time as Filipino standards, when much of the information is based upon assumption, unsupported by fundamental study of true measurements from representative numbers of individuals. If we desire to lead an efficient, modern, national existence, hand in hand with progressive countries, it is urgently necessary that sound vital statistics be collected and properly studied, as they constitute the very foundation of the efficient working out of national existence.

Knowledge of the standard lung capacity, or vital capacity, is particularly important in the Philippines in its relation to the study of certain phases of the question of pulmonary tuberculosis, admittedly the greatest scourge of the race. Pioneer observers in other countries, such as Garvin, Lungsgaard, and several others, have repeatedly demonstrated the necessity for conducting comparative determinations of the actual vital capacity and of the standard capacity in the early diagnosis of pulmonary tuberculosis. The determination and the finding of the existence of subnormal lung capacity per se, even in cases with intrathoracic affections other than pulmonary tuberculosis, require definite knowledge of standard data. In the Philippines this question is of great importance because of the peculiar condition of seeming susceptibility or state of predisposition of the Filipino to pulmonary tuberculosis. The present high rate of morbidity and mortality from this disease in all parts of the Philippines appears to suggest very strongly that a close relation may exist between the undeveloped or subnormal vital capacity and the heightened degree of susceptibility to pulmonary tuberculosis.

Indices of physical development and fitness of the body, such as stature, body weight, and chest circumference, are obviously needed, not only with the minor purpose of knowing how the race stands in physique as compared with other races of the world, but also because the standards derived from such measurements may be of assistance in attempts to solve the national problem of physical education in the public schools of the country. These statistical data are even concerned with the questions of correlation of normality with degree of efficiency, and doubtless enter into the consideration of such problems as insurance and the selection of applicants for various services, military, industrial, or otherwise.

Neither the physical nor the developmental standards of Filipinos have ever been properly investigated and determined. Un-

fortunately, exact and reliable data are not available. Various scattered records are possessed by several institutions in the Islands, but no study of real significance has ever been conducted on such records.

The present work is presented with the definite statement that it is only a preliminary step toward or an introduction to the opening up of a field of investigation purporting to appraise and determine the physical and developmental standards of the Malay peoples and, more specifically, of the Filipino race. The department of anatomy of the University of the Philippines more than three years ago commenced work on measurements of the external body dimensions and the internal organs of still-born babies and premature deliveries, with the purpose of determining the condition of embryological and foetal growth of Filipinos. The data so far gathered are limited, however, mainly because of the lack of men to undertake such work and because, consequently, the data so far gathered still fall short of the representative numbers requisite for useful report and summary. In connection with this, the department has a more comprehensive plan of undertaking a careful study of the physical condition of different groups, geographic or ethnic, of Filipinos with the purpose of better determining their developmental standards. However, much as the plan and purpose may mean, the department is seriously lacking in men for work of this kind, even with all the facilities already provided and arranged for by the department now available. Hope is entertained, however, that in the near future we may be granted such needed help for the proper determination of the much-needed standards.

It is partly because of the above reasons that the data dealt with in this preliminary study must be requisitioned from the department of physical education of the University of the Philippines. This department is conducting, yearly, measurements of some of the external body dimensions of Filipino students newly admitted to the university. The data do not include measurements of students of other nationalities. It would be of interest to know if these data pertain to that group of our population that may be called representative, and whether or not we are dealing only with a selected kind as far as physical development is concerned. No reliable answer can yet be given to this question; it can only be answered after careful study of different and more comprehensive data coming from all the various sources of the population, geographic and ethnographic.

We are using the records collected by the department of physical education. As is the case with any large collection of measurements, some errors arising from faulty technic were encountered in the examination of these records. These errors will be mentioned in the course of this study. Naturally they will to a certain extent affect some of our findings, but to no greater extent than should be expected in such work. It is desired again to emphasize the fact that this study is only a preliminary report, and that the errors mentioned have been fully recognized and considered, with the intention however of checking our findings more carefully in the future with data and measurements more systematically collected by ourselves.

MATERIALS FOR STUDY

The series of measurements dealt with were taken from seven hundred thirteen university students, five hundred sixty-four males and one hundred forty-nine females. This university-student population is made up of heterogeneous groups of young men and women coming from different parts of the Philippines. This heterogeneity will provide a general index of comparison for later investigations on regional studies of the Filipino people. The regional distribution of the university students examined is as follows:

	Per cent.
Ilocano region: Ilocos, La Union, Abra, Isabela, and Zambales Provinces	11.44
Pangasinan region: Pangasinan Province	8.05
Pampanga region: Pampanga and Tarlac Provinces	5.28
Tagalog region: Nueva Ecija, Bulacan, Batangas, Cavite, Laguna, Rizal, Tayabas, Mindoro, and Bataan Provinces	27.75
Bicol region: Camarines, Albay, and Sorsogon Provinces	0.63
Eastern Visayas region: Leyte, Samar, Cebu, Oriental Negros, and Bohol Provinces	3.81
Western Visayas region: Occidental Negros, Capiz, Iloilo, and Romblon Provinces	9.95
Mindanao region: Palawan, Zamboanga, and Misamis Provinces	0.84
City of Manila	32.20

The group studied comprises a blood intermixture, including Filipinos of the purely Malay type to those of close or distant Chinese and Spanish lineage. It also includes individuals with indefinite hybridism from among these principal constituent elements of mixed lineage.

The physical build of this group of university students, both male and female, varies somewhat, as can be seen from their external features alone. There are those of slender build, with poorly developed musculature, with apparently a disposition toward leading a sedentary life. Others possess good physique, with the body musculature fairly well developed. The latter individuals (who, by the way, constitute the marked minority in this series) are commonly known as the "athletic type." Intermediate between these two types are those who possess moderately developed musculature, and they seem to comprise the majority of the students. Among the females, however, there is apparently a predominance of the weaker and slender type, who appear indisposed to regular athletic exertion. This type seems to be more frequently observed among those coming from private schools.

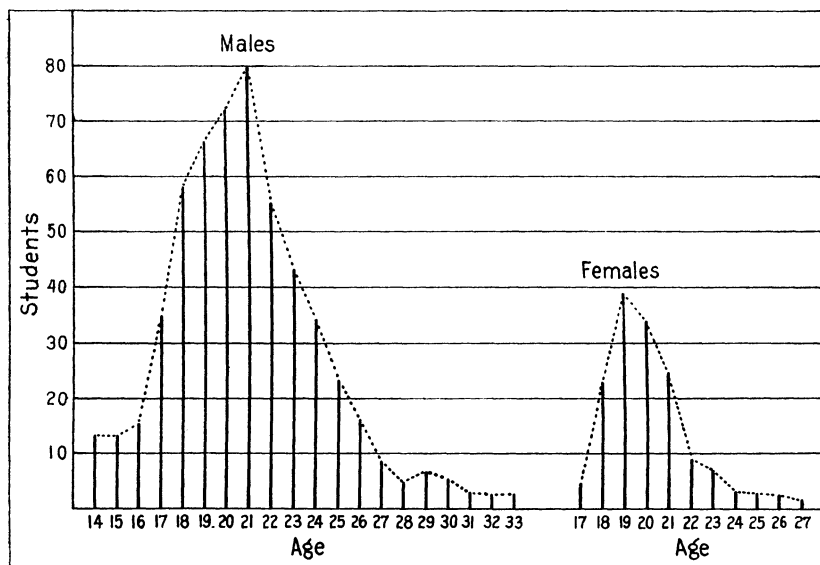


FIG. 1. Age frequency distribution of university students (University of the Philippines).

The extremes in age of males were 14 and 33 years, with the majority between 18 and 22; in women the age limits were 17 and 26 years, with 18 to 20 as the common mode. Figure 1 shows the age-frequency distribution for both male and female students. It is seen that the male students have a wider range of age than do the female students and that the former begin their university education at an earlier age than do the latter, and also that they continue their university attendance

for a longer period. The mean age of the male students in the University of the Philippines is 21 years, whereas that of the female students is 19 years.

TECHNIC OF MEASUREMENT

The vital capacity (lung capacity) is taken with a spirometer that gives accurate readings and registers the amount of air that can be exhaled after a maximum inspiration. This test is repeated three times with the same instrument, allowing an interval of several minutes for rest between tests. The average of the three readings is taken to represent the vital capacity of the individual; however, most workers take the maximum record made by the individual instead of the average as the vital capacity. For this reason, our records are a few hundred cubic centimeters lower than those of other workers.

The standing height is measured with a stadiometer provided with a horizontal slide moving at a right angle on a graduated perpendicular pole mounted on a box. The height is easily taken by having the individual stand erect and barefooted on the box and placing the slide on the top of his head. For taking these measurements, the head and figure of the subject are held erect, with the eyes to the front and the heels together. This position is better secured by having the back of the head, the spine of the seventh cervical vertebra, the buttocks, and the heels of the individual in contact with the measuring pole of the stadiometer.

The determination of the sitting height is also obtained with the stadiometer; but, instead of having the subject stand on the box, he is made to sit erect upon it, and the reading is made after the horizontal slide is placed on top of the head.

A steel tape measure is used for the determination of the chest circumference, both at rest and during maximum inspiration. The measurement of the chest is always made at the horizontal level of the nipples and with the subject standing. Only one measurement is taken in each case. The chest circumference of females is also measured as nearly as possible at the level of the nipple line. The variability in their case however is obviously influenced by the changeable position of the female breast, and such variation is given due consideration later.

The weight of the body is recorded by means of a platform scale with a high bar for appropriate reading. This scale carries the metric graduation and is sensitive to a fraction of

a gram. The weight of the males is taken without clothing; in the case of the females, however, it is regularly taken with the clothing and the necessary deduction is made of the approximate weight of the clothing, to get the net body weight.

NATURE OF INVESTIGATION

Some of the basic questions that we had in mind in our study are (a) the determination of the physical or constitutional make-up of the students of the University of the Philippines, (b) whether or not these students belong to the picked class in the Philippines as far as physical build is concerned, and (c) the relative standing of the physical development of Filipinos compared with the standards of the other oriental races and also with those of the occidental people.

The findings and discussions in this paper are limited to stature, body weight, build, vital capacity, chest circumference, and constitution. The other phases of the study will be presented in later papers which will also deal with the correlation of lung capacity and body weight with some of the most important external body measurements.

STATURE

We found the mean stature of the group of male Filipino university students to be 163.3 centimeters; the modal class for stature in the group, between 158 and 164 centimeters; the standard deviation, 5.91 centimeters. This degree of deviation implies only a fair degree of homogeneity in the class under study.

Results of a comparative study of the stature of several groups of university students of other countries (as gathered from references to available literature) and that of our group of students are presented in Table 1.

TABLE 1.—*Stature of various groups of university students.*

Group.	Stature.	Difference.	
	cm.	cm.	P. ct.
University of Oxford.....	176.5	13.2	8.1
Harvard University.....	175.9	12.6	7.7
Leland Stanford Junior University.....	173.6	10.3	6.3
University of the Philippines.....	163.3	-----	-----

It will be noted from Table 1 that the mean height of students of Oxford, Harvard, and Stanford Universities, as compared with the stature of Filipino students, is around 7 per cent, or

about 11.5 centimeters greater. This difference is in accord with the commonly admitted view that Filipinos as a whole are shorter in stature than are Americans and Britons.

The data on standing height, compared with that of non-university groups of European nationals, are given in Table 2.

TABLE 2.—*Stature of nonuniversity (military) groups of various nationals, compared with that of students of the University of the Philippines.*

National.	Stature.	Difference.	
	cm.	cm.	P. ct.
Scotch.....	172.5	9.27	5.67
English.....	172.1	8.81	5.39
German.....	172.0	8.77	5.37
Irish.....	171.4	8.09	4.95
Polish.....	169.4	6.14	3.76
French.....	168.6	5.32	3.26
Hebrew.....	166.9	3.64	2.23
Italian.....	165.2	1.91	1.17
University of the Philippines.....	163.8		

It is obvious from Table 2 that the stature of Filipino university students is around 6 per cent less than that of the northern or northwestern European nationals, and that it is around 2 per cent lower than that of the Latin or the Ibero-Mediterranean peoples. It appears from Tables 1 and 2 that, as far as male stature is concerned, that of the university group, for both the Britons and the Americans, is superior to that of the military groups.

Standing height of Filipinos compared with that of some of the Mongolian and oriental races of nonuniversity groups (records on students not being available) shows certain differences, as indicated in Table 3.

TABLE 3.—*Standing height of nonuniversity groups of Mongolian and oriental races compared with that of students of the University of the Philippines.*

Race.	Stature.	Difference.	
	cm.	cm.	P. ct.
North Chinese.....	167.1	3.8	2.3
South Chinese.....	163.1	—0.2	—0.1
Koreans.....	162.2	—1.1	—0.7
Siamese.....	160.8	—2.5	—1.5
Japanese.....	159.7	—3.5	—2.1
University of the Philippines.....	163.3		

The North Chinese, the tallest of all the Mongolian races studied, show but little difference (not quite 4 per cent) over the Filipino standard. The figures for stature of the North Chinese was obtained from soldiers, as were also those of the other oriental races except the Siamese, which were obtained at random from the civilian population. The standing height of the South Chinese, however, shows close relationship with that of Filipinos (163.3 for the Filipinos, and 163.1 for the South Chinese), presenting therefore a difference of only a fraction of 1 per cent. This particular finding seems to point to the existence of relationship between the people of the two groups, as has been asserted and accepted by many historians and ethnographers of Asia and the Malay Peninsula.

The stature of the Japanese, the Koreans, and the Siamese is seen to be distinctly lower than that of the university-student group in the Philippines. This statement appears to be borne out by statistical comparison, in spite of the fact that our data for the first two were obtained from the military population of those two races. The difference between Filipino and Japanese stature amounts to a little over 2 per cent. Between the Filipino and the Siamese it is nearly 1.5 per cent, and between the Filipino and the Korean it is 0.7 per cent.

Statistical studies on stature have evolved the general classification of the average height of men shown in Table 4.

TABLE 4.—*Average height of men.*

	cm.
High stature	Over 170
Stature above the average	165 to 169
Stature below the average	160 to 164
Low stature	Under 160

According to this classification the standing height of the students of the University of the Philippines, as shown by our records, would fall under the group of "Stature below the average."

BODY WEIGHT

The average body weight of Filipino university males is 50.75 kilograms; the modal class for weight ranges from 45 to 55 kilograms. This class comprises 61.2 per cent of all of the male students. The standard deviation existing in our group for the body weight is 6.22 kilograms. It has been found that individual variation in body weight is more marked and more irregular in our group of university students than in other, foreign university groups.

A study of our standards on body weight, including actual and percentage differences, compared with those of other university groups of several occidental races, has afforded the interesting comparative figures shown in Table 5.

TABLE 5.—*Body weights of student groups in other universities compared with those of students of the University of the Philippines.*

Group.	Body weight.	Difference.	
	kg.	kg.	P. ct.
University of Oxford.....	68.5	17.75	34.9
Leland Stanford Junior University.....	68.4	17.35	34.1
Harvard University.....	64.5	13.75	27.1
University of the Philippines.....	50.6		

It will be seen from Table 5 that our university males have an average body weight that is 35 per cent less than that of the English males of Oxford or that of the American students of Stanford, and about 27 per cent less than the average body weight of the students of Harvard. These differences amount to around 17.5 kilograms more for Oxford and Stanford and 13 kilograms for Harvard over and above the Filipino weight.

The body weight of our students, compared with that of groups of European races, taken from nonuniversity populations, is seen to be no less striking (see Table 6).

TABLE 6.—*Body weight of nonuniversity groups among other nationals compared with that of students of the University of the Philippines.*

National.	Body weight.	Difference.	
	kg.	kg.	P. ct.
German.....	67.2	16.4	32.3
Polish.....	66.0	15.2	29.9
English.....	65.8	15.0	29.5
Scotch.....	65.7	14.9	29.3
Irish.....	64.8	14.0	27.5
French.....	64.5	13.7	26.9
Italian.....	62.6	11.8	23.2
Hebrew.....	62.5	11.7	23.0
University of the Philippines.....	50.8		

Following the comparison farther, with other races, such as the Mongolians, we found that there also exist certain differences that must be emphasized in their relation with the weight standard of the Filipino university students. Table 7 brings out clearly these differences for some of the Asiatic races.

TABLE 7.—*Body weight of groups among Mongolians compared with that of University of the Philippines students.*

Group.	Body weight.	Difference.	
	kg.	kg.	P. ct.
North Chinese.....	59.3	8.5	16.7
Koreans.....	58.6	7.8	15.3
Japanese.....	55.5	4.7	9.2
South Chinese.....	50.6	—0.2	—0.3
University of the Philippines.....	50.8		

From Table 7 it is seen that the principal Mongolian races, except the South Chinese, have a greater body weight than do the students in the University of the Philippines. This difference with respect to the Japanese is a point of some importance, because of the fact that, while the Filipinos exceed them in stature by nearly 4 centimeters (the stature of the Japanese is 159.7 centimeters and that of our group is 163.3 centimeters), yet comparison of the body weights shows that the Japanese are 9.2 per cent heavier, a difference amounting to about 4.7 kilograms. Such finding speaks strongly of low body nutrition or of poor body development in our students, and very likely also of Filipinos in general.

It should be mentioned that, for a study on stature and body weight of various races, we do not consider the comparison between groups of university students and military groups entirely satisfactory and free from criticism; but, in the absence of records obtained exclusively from the student populations of other races, we had to make use of the standard data available, so long as such records were to a fair degree comparable and bore a proximal relationship to those obtained from university groups. The standard physical measurements recorded for English and for American students demonstrate a higher degree of physical development than do those of their military populations. It would seem therefore that the physical records of the armies of other races would be to a certain degree comparable with the standard of measurements obtained from our group of university students. It might be well also to mention in this connection that the body measurements and the degree of physical development of our university students probably do not maintain the superior development over the military standards of our own race that exist among the English and the Americans.

UNIT WEIGHT AND BUILD

Some of the most important observations met with in the study on stature and body weight of Filipinos, as compared with those of other university groups and races, are those related to the serial excess of absolute standards of height and weight of the latter over our group, which seem to reflect considerable light upon the nutritional condition of the Filipino race.

The weight of the body, considered in relation to stature, offers one of the most important indices of physical condition, or build; that is, the index of physical efficiency. It is to be observed from the foregoing tabulations that the excess in the stature of the students of Oxford, Harvard, and Stanford over that of the Filipino group is associated with marked excess of body weight to a degree much greater than we expected to find; thus, while the differences in height over the Filipino standards were 8, 7.7, and 6.3 per cent, respectively, those of body weight recorded a much higher degree of superiority over the Filipino weight, amounting in actual figures to 34.9, 27.1, and 34.1 per cent, respectively, for Oxford, Harvard, and Stanford.

Our findings appear to show that body nutrition and body development in the group under study are considerably lower than in the groups of English and American students; that is, the lesser body weight of our students is too much out of proportion to their shorter stature, when compared with the difference in foreign students. This poorer condition of nutrition and development would indicate that, for a given unit of stature, there would be a corresponding lower body weight for Filipino students. The body weights per centimeter of stature of the university and the military groups are shown in Table 8.

TABLE 8.—*Body weight per centimeter of stature of University student groups and foreign military groups.*

Group.	Grams.
Leland Stanford Junior University	390.8
University of Oxford	389.2
Harvard University	372.8
University of the Philippines	311.0
German	390.8
Polish	390.8
French	383.0
English	382.2
Scotch	382.2
Italian	379.3
Irish	379.2
Hebrew	376.6

The figures in Table 8 show conclusively that the per centimeter unit of stature of the students of the University of the Philippines carries an equivalent of only 311 grams of body weight, whereas in the case of English and Americans the equivalents are around 384 grams. There is a difference therefore of more than 70 grams per centimeter unit of stature. This fact obviously indicates that the state of nutrition of Filipino students is far below that of students of occidental races. The absolute expression of equivalents for the nonuniversity groups of various races points also unequivocally to the poorer state of body nutrition and development of our students, and probably also of the Filipino people as a whole.

If this study is carried farther and the unit relation of stature to body weight as observed in some of the oriental races is compared with that for our students, it will be found that there exist also noteworthy differences which reflect the lower degree of body nutrition and physical state of the Filipino students (see Table 9).

TABLE 9.—*Body weight per centimeter of stature of Orientals and of University of the Philippines students.*

Group.	Grams.
Koreans	361.7
North Chinese	354.0
Japanese	349.0
South Chinese	310.4
University of the Philippines	311.0

The most important finding in the data for the oriental or Mongolian races is the existence again of differences that place our standard of measurements below the standards of neighboring races. Despite the fact that the stature of the Japanese is 3.5 centimeters, or 2.1 per cent, less than that of the Filipino, yet the body weight of the former is greater by 4.2 kilograms, or 9.2 per cent. The Japanese weight per centimeter unit of stature amounts to 249 grams, in contrast to 311 grams for the Filipino students. The stature of the Korean is a fraction of 1 per cent lower than the Filipino height, and yet his body weight is 15.3 per cent greater. The stature and weight of the South Chinese are closely similar to the standards for our group and, further, their per centimeter unit of stature is almost parallel to that of the students of the University of the Philippines. A considerable difference is observed in the data for the North Chinese; their stature is only 2.3 per cent higher than ours, yet their body weight is greater by 16.7 per cent.

It appears, therefore, that we must accept and admit the conditions revealed by the comparative figures given above. They are unfortunately against the physical standing of our race, as proven by mathematical analysis of actual measurements of a fair number of individuals, from a fairly known degree of social standing. The existence of such conditions can be explained, perhaps, by such factors as social standing, climate, and financial standing, which factors should be carefully studied so that institutions responsible for the welfare and well-being of our race can devise necessary and definite measures for the effective correction and improvement of such conditions.

The determination of the index of build for any particular group or class of people takes into consideration the body weight in relation to stature. According to Guild and Quetelet the formula that is most satisfactory for the solution of the index of build is one that takes the ratio of weight divided by the second power of the stature, namely:

$$\frac{\text{Weight } (\times 1,000)}{\text{Height (sq.)}} = \text{Build.}$$

In accordance with this formula we have found the following indices of build for the various university and racial populations that we have been considering:

TABLE 10.—*Index of build for university student groups and foreign military groups.*

Group.	Index.
Leland Stanford Junior University	22.33
University of Oxford	22.11
Harvard University	21.55
University of the Philippines	19.12
Koreans	22.32
Japanese	21.95
North Chinese	21.26
South Chinese	19.04
Polish	23.10
Italian	22.99
French	22.85
German	22.71
Hebrew	22.68
English	22.24
Scotch	22.20
Irish	22.16

Table 10 shows definitely that the body development of Filipino students is below that of the university or nonuniversity groups of the other races listed. The only racial group shown to

possess the same index of build as that of the Filipino is the South Chinese.

VITAL CAPACITY

The average vital capacity that we found for the male students of the University of the Philippines is 2,262 cubic centimeters. The modal class, covering 35.3 per cent of the males in our series, ranges from 1,600 to 2,000 cubic centimeters. The standard deviation in the vital capacity of this group amounts to 66.93 cubic centimeters.

In our study of the various standards on vital capacity of the different groups of university students of other nationalities we were greatly astonished to find that the record for our group ranks far below the standards of the others. This was also found to be true on comparison with some of the oriental races, but the differences are not so glaring as are those from the other data.

The average vital capacity of our students is only 2,262 cubic centimeters; that of the Oxford, Harvard, and Stanford University students averages as high as 4,315, 4,651, and 4,646 cubic centimeters, respectively. There exist, therefore, the overwhelming excesses of 2,055 cubic centimeters for Oxford, 2,389 cubic centimeters for Harvard, and 2,384 cubic centimeters for Stanford over the vital-capacity standard of our university students. These differences, expressed in percentages, are given in Table 11, both for the university groups and for some of the nonuniversity oriental groups.

TABLE 11.—*Vital capacity of University of the Philippines students compared with that of Mongolian nonuniversity groups.*

Group.	Vital capacity.	Difference.	
	cc.	cc.	P. ct.
Harvard University.....	4,651	2,389	105.6
Leland Stanford Junior University.....	4,646	2,384	105.4
University of Oxford.....	4,315	2,053	90.7
Americans (nonuniversity).....	3,602	1,340	59.2
North Chinese.....	3,180	918	40.5
South Chinese.....	2,518	256	11.3
University of the Philippines.....	2,262		

Comparison of the figures in Table 11 shows the superior volumetric lung contents of 90 per cent for Oxford and 105 per cent for both Harvard and Stanford over the vital capacity of our group. In other words, this finding means that English

and American students can inspire double the amount of air that Filipino university males can take in, and that the lungs of the former groups have twice the degree of expansion, compared with the lungs of Filipinos. This is again a finding on actual conditions that is to be regretted, but which we must accept as it is borne out by the results of the analytical study of actual measurements.

It was not possible to continue the parallel study of the standards on vital capacity of the other races, because no complete data on the subject were obtainable in the statistical reports at our disposal.

The significant fact in connection with the vital capacity of Filipino students is the parallel between their capacity standard and their stature and body weight standards, as compared with the corresponding standards of other nationalities. It has been stated earlier in this paper that the body weight of Filipino students falls below and is out of proportion to the fall in stature observed in the students of Oxford, Harvard, and Stanford and that, though the fall in stature is only around 7 per cent, the fall in weight is around 35 per cent. If the vital capacity is examined along the same lines, it will be found again that the capacity of Filipino university students is much lower, even about 50 per cent of the vital capacity of English and American university students.

The finding on the vital capacity is a practical demonstration of facts on the vital resistance of Filipino university students and, we venture to say, of Filipinos in general. It is probably reasonable to presume that, if differences exist in the standards of the various social groups of the Filipino race, the vital capacity of the university population should present a higher standard than we would expect to find from the rest of our population, with the possible exception of the military group. The too inferior relative standing of the university capacity standard, in relation to other races, is regrettable, but the finding should be seriously taken into consideration by those among us who are responsible for the promotion of the health and the well-being of the people, and more particularly by those called upon to solve the vital national question of pulmonary tuberculosis. The very poor standard of vital capacity found in Filipino young men may be one of the most important factors contributing to the extraordinarily high rate of morbidity and mortality from pulmonary tuberculosis.

CHEST CIRCUMFERENCE

Chest circumference is a dimension of some importance, from the medical, the military, and the anthropological points of view. It is sometimes used to measure the lung capacity, and it serves also in some cases as an index for the determination of certain pulmonary diseases. This measurement is employed in obtaining the index of robustness, an index that is generally considered to offer a fair measure of the vital resistance of the individual.

The mean chest circumference found by us in our group of university males is 79.9 centimeters. The modal class of this measurement is from 78 to 82 centimeters and comprises about 39 per cent of the males in this series. The standard deviation of this dimension is 5.59 centimeters.

A comparative study of the Filipino standard chest circumference and of the records for other racial groups resulted in the figures presented in Table 12, which show the actual differences computed in percentages.

TABLE 12.—*Chest circumference of Filipino university students compared with that of other racial groups.*

Group.	Chest circumference.	Difference.	
	cc.	cc.	P. ct.
Siamese.....	84.5	4.6	5.7
Korean.....	82.9	3.0	3.7
Japanese.....	82.2	2.3	2.9
North Chinese.....	81.4	1.5	1.9
South Chinese.....	81.3	1.4	1.8
University of the Philippines.....	79.9		
Polish.....	90.4	10.5	13.1
German.....	89.5	9.6	12.0
Italian.....	88.9	9.0	11.3
Irish.....	88.7	8.8	11.0
Scotch.....	88.6	8.7	10.9
French.....	88.5	8.6	10.8
English.....	88.2	8.3	10.4
Hebrew.....	87.5	7.6	9.5

The standard of chest circumference for Filipinos is seen to be lower than that of any of the other races. We could not compare our records of this measurement with those of other university groups because we were unable to locate standard data on chest circumference for university males of other races.

CONSTITUTION, OR ROBUSTNESS

The index of constitution, or robustness, of individuals depends upon certain relations of stature, weight, and chest circumfer-

ence. This index is generally calculated according to the following formula:

Constitution=Stature in centimeters—Chest circumference in centimeters+Weight in kilograms.

The table of standards commonly accepted by known authorities offers means for the right interpretation of results as obtained by the above formula for the determination of constitution. Table 13 shows standards as proposed by Pignet.

TABLE 13.—*Indices of constitution, or robustness, according to Pignet.*

- Class A, under 10, a very powerful constitution.
- Class B, 11 to 20, good constitution.
- Class C, 21 to 25, mediocre constitution.
- Class D, 26 to 30, weak constitution.
- Class E, 31 to 35, very weak constitution.
- Class F, over 36, bad constitution.

On the basis of the above formula, we find that the robustness, or constitution, of male students of the University of the Philippines reaches the low index of 32.6. According to the classification of Pignet this index value falls under the class of "very weak constitution." This result is only to be expected from the figures for the other Filipino standards as compared with the physical measurements of other races. The following comparative list of the indices of constitution (Table 14) further emphasizes the lower records of Filipinos as compared with those of others. It is to be noted that the lower the expression of values the better the degree of constitution, or robustness.

TABLE 14.—*Comparative constitution indices.*

Nationality.	Index.
Polish	12.9
Italian	13.7
German	15.3
French	15.6
Hebrew	16.9
Irish	17.8
English	18.1
Scotch	18.2
Korean	20.7
Japanese	22.0
North Chinese	26.4
South Chinese	31.1
University of the Philippines	32.6

No index of constitution is available for foreign university groups because of the lack of data on chest measurement on which this index is partly computed; but probably the English

and American student groups possess better constitution, or robustness, than do the military population, their other physical standards being superior. Table 14 demonstrates that the student population in the Philippines is unfortunately far below that of other races of the world in comparative constitutional standing, and it behooves us earnestly to study the question of improving the deplorable physical development and body nutrition of the Filipino race.

SUMMARY OF FINDINGS IN THE MALE GROUP

Our findings and results for the male group are summarized in Table 15.

TABLE 15.—*Summary of measurements of Filipino males.*

Measurements.	Means.	Modal class.	Standard deviation.
Stature..... cm	163.3	158- 164	5.91
Body weight..... kg	50.6	45- 55	6.22
Vital capacity..... cc	2,262.0	1,600-2,000	66.93
Chest circumference..... cm	79.9	78- 82	5.59
Sitting height..... cm	85.2	83- 89	5.11

The indices of the students of the University of the Philippines are: Body weight per unit stature, 311 grams; build, 19.1; and constitution, or robustness, 32.6.

TABLE 16.—*Differences in percentage of physical standards.*

Group.	Stature.	Weight.	Vital capacity.	Chest circumference.
Oxford.....	8.1	34.9	90.7	-----
Harvard.....	7.7	27.1	105.6	-----
Stanford.....	6.3	34.1	105.4	-----
North Chinese.....	2.3	16.7	40.5	1.87
South Chinese.....	-0.1	-0.3	11.3	1.87
Japanese.....	-2.1	9.2	-----	2.87
Korean.....	-0.7	15.3	-----	3.75
Siamese.....	-1.5	-----	-----	-----
Scotch.....	5.67	29.3	-----	10.88
English.....	5.39	29.5	-----	10.28
German.....	5.37	32.3	-----	12.01
Irish.....	4.95	27.5	-----	11.01
Polish.....	3.76	29.9	-----	13.14
French.....	3.26	26.9	-----	10.76
Hebrew.....	2.23	23.0	-----	9.51
Italian.....	1.17	23.2	-----	11.26

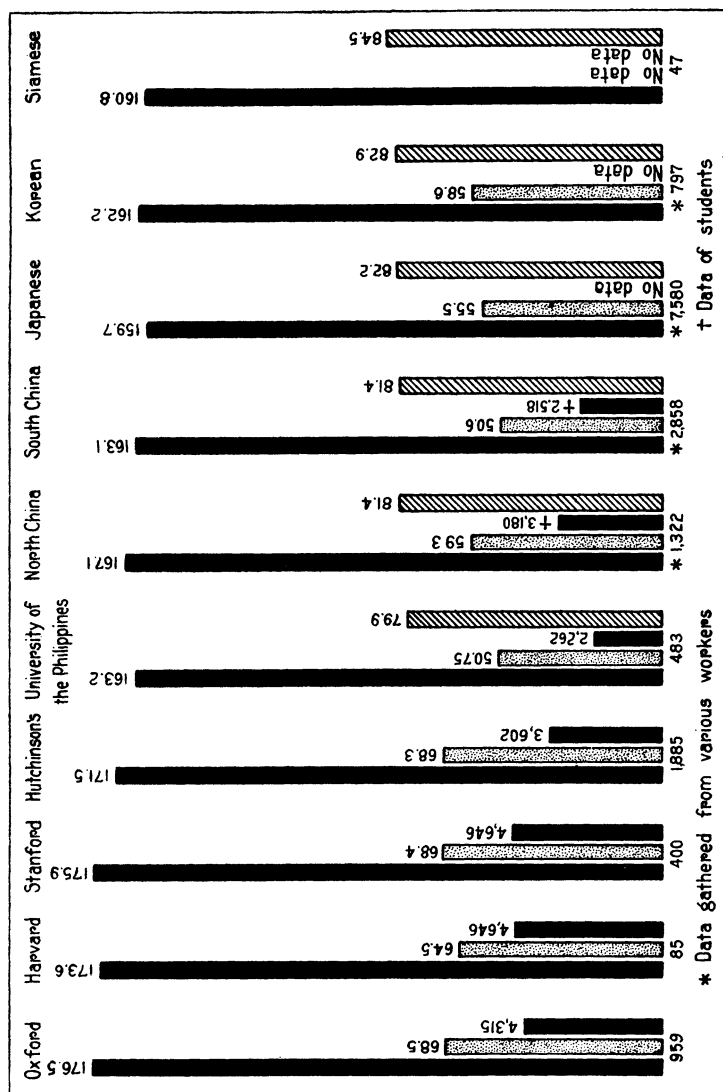


FIG. 2. Graphic comparison of physical measurements of several university groups together with those of some oriental races (male).

The differences in percentage of the physical standards that the university and nonuniversity groups of other races show over the physical standards found by us for the University of the Philippines are expressed in Table 16. The few negative percentage values encountered in the computation of this table are indicated by the minus sign.

Table 17 is a comparative summary of Filipino physical standards obtained for the student group under study and for those of other races from university and nonuniversity populations. (See also fig. 2.)

TABLE 17.—*Summary of physical standards of Filipino male university students compared with those of other races.*

University group.	Stature.	Weight.	Weight per unit stature.	Build.	Vital capacity.	Chest circumference.	Constitution (robustness.)
	cm.	kg.	g.		cc.	cc.	
University of the Philippines.....	163.3	50.8	311.0	19.1	2,262	79.9	32.6
Oxford.....	176.5	68.5	389.2	22.1	4,315	-----	-----
Harvard.....	173.6	64.5	372.8	21.5	4,651	-----	-----
Stanford.....	175.9	68.4	390.8	22.3	4,646	-----	-----
North Chinese.....	167.1	59.3	354.8	21.3	3,180	81.4	26.4
South Chinese.....	163.1	50.6	310.4	19.0	2,518	81.4	31.1
Japanese.....	159.7	55.5	349.0	22.0	-----	82.2	22.0
Korean.....	162.2	58.6	361.7	22.3	-----	82.9	20.7
Siamese.....	160.8	-----	-----	-----	-----	84.5	-----
Scotch.....	172.5	65.7	382.2	22.2	-----	88.6	18.2
English.....	172.1	65.8	382.3	22.2	-----	88.2	18.1
German.....	172.0	67.2	390.8	22.7	-----	89.5	15.3
Irish.....	171.4	64.8	379.2	22.2	-----	88.7	17.8
Polish.....	169.4	66.0	390.8	23.1	-----	90.4	12.9
French.....	168.6	64.5	383.0	22.8	-----	88.5	15.6
Hebrew.....	166.9	62.5	376.6	22.7	-----	87.5	16.9
Italian.....	165.2	62.6	379.3	23.0	-----	88.9	13.7

DISCUSSION OF FINDINGS

The very noticeable inferiority of Filipino physical standards compared with the standards of other racial groups referred to in this work indicates a deficient, low body nutrition in Filipinos and a serious lack of regularly conducted physical exercise.

The degree of inferiority observed in the various standards seems to show that it is the weight element or the weight per unit-stature ratio that is markedly low in our group. This fact has been repeatedly emphasized in this paper. Low body weight may of course be due to various factors; such as (a) the existence of a chronic disease that causes certain metabolic disturbances and produces emaciation, (b) the presence of certain parasites claimed to be peculiar to the Tropics and which

tend to undermine the health of the individual harboring them, or (c) actual undernourishment.

The particular group now under study belongs to the social population of the country that is expected to possess better body nutrition than any other social group of the race. University students, as a general rule, come from families that are fairly well to do and are in financial position to provide their children with better support and better nourishment than the majority of our children can have. In fact, our University students should belong to the classification of "picked class," as far as nutritional possibilities are concerned, and their standards should be better than those of the larger groups of our population. It is presumable, therefore, that the standards on physical data of the other social groups of the Filipino race would fall below those shown by the records of the students.

Deficient body nutrition in these students does not appear to be due to the presence of chronic diseases among them. The students of the University of the Philippines are subjected to a rather thorough physical and medical examination at the opening of every academic year. Those found suffering from some chronic disease are either not accepted or are recommended to leave the school for proper treatment. Therefore, it is fair to assume that the data here reported are records from a normal group and that the deficient body nutrition observed from the study of their standards is probably not due to the presence of chronic disease among them.

We do not consider that parasitic infection is an important factor in producing the poor physical condition of our students. It is believed that these university students are living in fairly good sanitary and hygienic surroundings, the majority being members of fairly well-to-do families, and that the degree of exposure to which they are being or have been subjected is probably slight, compared with the greater mass of the inhabitants. Certainly, even if some of them were infected, the number would probably not be sufficient greatly to influence the average or the mean body weight of the whole group. A survey of the incidence of parasitic infection among students would be interesting and important, especially if the extent of the influence that such parasitic infection exerts upon the condition of low body nutrition among the students of the University of the Philippines could be determined.

We are inclined to believe that undernourishment in Filipino students, due to insufficiency in form or kind of subsist-

ence, is the most important contributing factor in causing underweight in our university group. There is probably not so much insufficiency of food and nourishment as there is lack of balance in the diet of Filipinos. Much preliminary work has been carried out on the determination of a balanced diet for Filipinos, and it is admitted that there is lack of a properly balanced diet in the daily subsistence of Filipinos in general. In the work of Roxas and Collado on the Filipino diet, as conducted on some of the students and members of the families in the College of Agriculture at Los Baños, the following assertions are worthy of note:

* * * in what we would consider a good Filipino diet, grain products supply 75.16 per cent of the calories, while animal products supply only 11.35 per cent * * * that animal protein constitutes 30.88 per cent of the total protein and that the grains furnish over one-half (5.10 per cent) of the total protein. While the vitamine carriers in the American diet (eggs, milk, cheese, vegetables, butter, fruits) furnish 33.99 per cent of the total calories, in the Student Mess dietary the vitamine carriers constitute only 10.55 per cent, and in the diet of the peasant families they are in even smaller proportion, only about 5 per cent. It is thus apparent that the so-called protective foods constitute only a small percentage of our diet. Only about 15 per cent of our food, as against 40 per cent of the American, is of animal origin. Milk and dairy products, which according to McCollum, are the protective foods *par excellence*, constitute an insignificant part of our dietary.

The above conclusions of Roxas and Collado are sustained by other workers who have done work on the quality and value of Filipino foods; for instance, Aron and Concepcion. They agree that the main defect in the Filipino's every-day food is lack of proper balance, with special reference to the limited amount of vitamine and calcium carriers in the ordinary diet. Table 18 on dietary standards of Filipinos and of other races shows that the diet of Filipinos is not deficient in caloric value, but the mixture appears to be wrong.

TABLE 18.—*Comparison of dietary standards in different countries.*

[Langworthy's compilation.]

Country.	Occupation.	Protein.	Calories.
United States.....	Farmers.....	71.5	2446.5
Canada.....	Laborers.....	77.2	2485.5
Japan.....	do.....	87.2	2190.0
China.....	do.....	91.0	3400.0
Egypt.....	do.....	112.0	2825.0
Congo.....	do.....	108.0	2812.0
Philippines.....	Students (Ag). ..	78.1	2675.0

It is believed that most Filipinos have not yet learned to recognize the importance of certain articles of food that are highly essential for the proper upbuilding and development of the body. The actual condition is that, though those essential food articles are at present obtainable, the prices are prohibitive for the greater portion of our people, and their use and consumption are, therefore, far from general. There seems to exist the vicious circle of lack of an effective campaign for the consumption of the proper food on the one hand and lack of sufficient production of those essential constituents of diet owing to slight demand on the other. This condition has the aggravating consequence of an almost permanent high rate of prices. These principal factors in the vicious circle must first be remedied, and the millions of families in their search, cultivation, and selection of food articles must be effectively influenced if it is intended that these essential constituent elements be included in the daily diet of the general mass so that body development and body efficiency may reach the maximum.

We feel positive that the much lower standard of vital capacity demonstrated by the physical records of Filipino university males is due to the serious lack of regularly conducted physical exercise among the great mass of our children and young people. There is great need of exercise that will help bring about greater expansion of the chest and thus produce greater capacity for intake of air in the alveoli of the lungs. Taking into consideration the still serious question of pulmonary tuberculosis that affects a considerable portion of our population, this problem of physical and respiratory exercise becomes of paramount importance. It is believed that there is positive hope of decreasing the morbidity from pulmonary tuberculosis if the resistance of the lungs be strengthened by general prescription and careful supervision of correct physical and respiratory exercise. Such a campaign must be based, of course, on improved dietary provision for the people.

Physical exercise indifferently and irregularly followed at variable intervals, as is the practice in some of the schools in the Islands, would not bring about good chest and lung expansion in our children. Moderate respiratory or pulmonary exercise should be prescribed, together with the routine physical and calisthenic regimen in our schools. It is believed that the calisthenic and other exercises prescribed in the public schools are

not sufficiently supervised and uniformly regulated to effect fair development of the body musculature and to produce proper expansion of the chest. The practice of conducting interscholastic athletic competitions in the different regional groups of the Philippines, although beneficial socially, educationally, and physically, is not exactly productive of generalized and wholesale improvement in the physical build of the great mass of our population. Such competition probably results in the physical betterment of a few, only a small fraction of the mass of students in the public schools.

Physical exercise should be provided for a much larger part of our population. This does not mean that the interscholastic competitions are undesirable; on the contrary, they should be promoted in such manner as to serve as a stimulus toward a general love for out-door exercise and sports, and they should be made more comprehensive so that greater benefits may be derived from them. It is certainly a matter for pride that in the Far Eastern Athletic Meet among the oriental races conducted in the last few years, Filipino athletes have been credited with winning a large number of points from their competitors. However, it is regrettable that, when the physical build and the vital capacity of the same contending oriental peoples are compared, Filipinos fall behind the others. In other words, the paradox is presented of the Filipinos, though victors, being physically inferior to their vanquished foes. Therefore, we should strive for the wholesale and general physical improvement of the Filipino race.

PHYSICAL MEASUREMENTS OF FEMALE STUDENTS OF THE UNIVERSITY OF THE PHILIPPINES

We are skeptical in reporting the observations and findings met with in the study of our data on the female group of our students. This is due to the fact that the number of this group is not sufficiently comprehensive to admit of valuable statistical interpretation, as the female records cover but 166 individuals. Furthermore, we found several questionable points, arising either from the procedure of recording or from the peculiar individual reaction of the subjects during the process of measurements. The female students seem to have shown indifference, hesitation, or bashfulness in the recording of certain measurements and failed to cooperate fully with the technician.

Because of the above reasons the findings and standards presented here are submitted as a preliminary survey only; it is believed that they may be of some interest.

The age-frequency distribution of the group is shown in fig. 1, and shows that the modal class for age is from 18 to 20 years, with the mean age of 19 years for the female university students. The graph also indicates that the female students have a narrower range of age than the university males, for the former between 17 and 27 years and for the latter between 14 and 33 years.

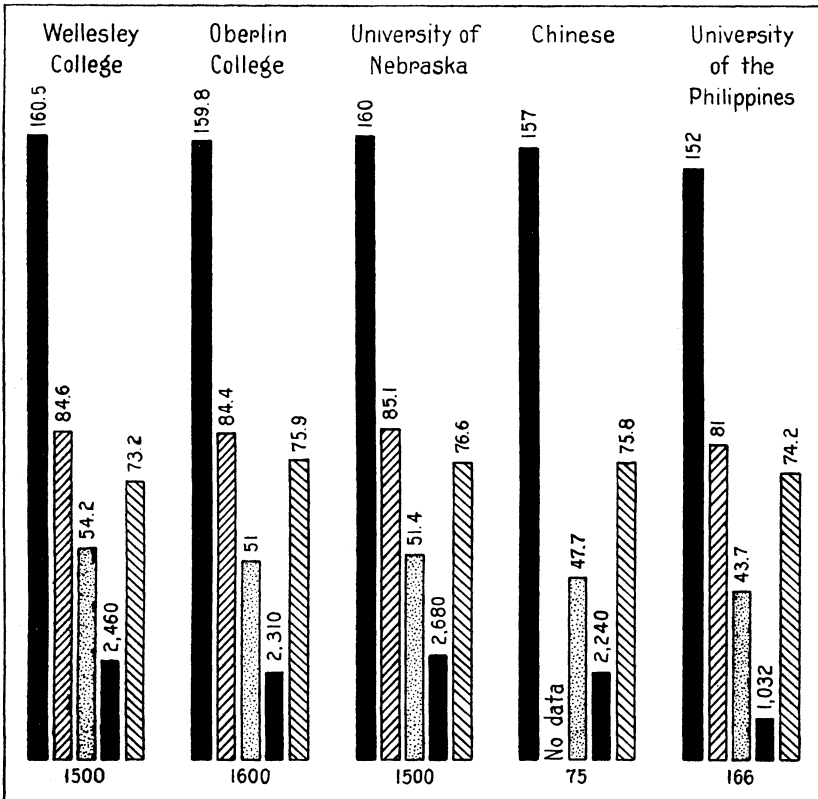


FIG. 3. Graphic comparison of physical measurements of several college groups (female).

STATURE

The mean stature found for the university females is 152.2 centimeters. The modal class for stature is between 150 and 156 centimeters, with a group comprising a little over 51 per

cent of the individuals. The standard deviation existing for stature is 4.69 centimeters. It appears that this record verifies the common admission that Filipino females are lower in stature than their sisters in the American universities. The comparative standing between the standard of American college women and that of our own in stature is shown in Table 19; see also fig. 3.

TABLE 19.—*Comparison of stature of university women.*

	cm.
Wellesley College	160.5
Oberlin College	159.8
University of Nebraska	160.0
University of the Philippines	152.2

According to Table 19, the height of Filipino college women is around 5 per cent lower than that of American college women. We were unable to compare this measurement with that of female students of European universities and colleges, as we could find no literature pertaining to this subject in the local libraries. Comparison with the records on stature for Chinese women shows that the Filipino standard is lower than theirs, which is recorded as 157 centimeters. We failed to find standard data on the Japanese or other oriental races with which to compare the Philippine.

BODY WEIGHT

The average body weight found in this group is only 43.2 kilograms. The modal class in weight is between 35 and 45 kilograms, the group comprising 56.2 per cent. The standard deviation for this measurement is 5.42 kilograms.

As in the case of the body weight of male university students, that of the female group is far below the standard body weights of American college women. The difference amounts to around 20 per cent in favor of the Americans. The body weights of female students in the three American colleges referred to above and of those in the University of the Philippines are shown in Table 20. (See also fig. 3.)

TABLE 20.—*Comparison of body weights of university women.*

College group.	Body weight.	Difference.
	kg.	P. ct.
Wellesley College.....	54.2	24.0
Oberlin College.....	51.0	16.7
University of Nebraska.....	51.4	17.6
University of the Philippines.....	43.2	

It is obvious that there exists a considerable difference in the fall of both stature and weight from the corresponding standards of foreign college groups. Whereas the difference in stature is only around 5 per cent, that of body weight is around 20 per cent in favor of the Americans. The ratio of weight to stature or the body weight per unit stature in our group amounts to only 287.1 grams (per centimeter of stature), whereas that of the American college women amounts to a little more than 325 grams. There exists therefore a difference of about 38 grams per centimeter of stature. The weights per unit stature of Wellesley, Oberlin, and Nebraska are, respectively, 337.6, 319.1, and 321.2 grams.

The lower degree of body weight in the male and female groups of Filipino university students indicates that there must be present some generalized factor or factors that influence the condition of nutrition of the latter.

BUILD

Build is defined in the first part of this paper as the weight of the body in relation to stature or, more definitely, it is the weight multiplied by 1,000 and divided by the square of the stature. It offers one of the most important indices of the physical condition of individuals or groups of people. We found the relative standing of the build of the various college groups to be as indicated in Table 21.

TABLE 21.—*Comparison of build of university women.*

Wellesley	21.2
Oberlin College	20.2
University of Nebraska	20.1
Chinese	19.3
University of the Philippines	18.9

It will be seen from Table 21 that in build the Filipino university women are inferior to Americans and even inferior to Chinese women. We should like to have compared the standard of build of the Filipino group with that of the Japanese and of the different European female groups, but failed to find any literature on the subject with respect to those races. From actual observations on the body condition and size of Japanese women it appears more than likely that in build their standard is higher than is that of Filipino women.

VITAL CAPACITY

In this measurement we believe some questionable errors have occurred in recording, as extraordinary difference and variation

in the interrelation of the vital capacity and the chest circumference were found in the records of individuals. Possibly, the women from whom the measurements were obtained failed to coöperate in making the records for vital capacity, or perhaps they were not properly instructed how to use the spirometer. The clothing was not removed when the chest measurement was being taken and, in the majority of cases, the inspiration and expiration figures in recording the vital capacity were not fully and uniformly registered. Our finding in this regard is given below as a mere exposition of data, and our conclusions are based on surmise and are subject to future checking and verification.

The average vital capacity found for this female group is 1,032 cubic centimeters. The modal class for this measurement is between 900 and 1,020 cubic centimeters, comprising a little over 59 per cent. The standard deviation is 26.5 cubic centimeters.

The vital capacity recorded is found to be much lower than the standard reported for the vital capacity of college women from Wellesley, Oberlin, and University of Nebraska, the records for which are 2,460, 2,310, and 2,680 cubic centimeters, respectively. The differences observed are so obvious that further emphasis does not seem necessary. The Filipino records, compared with the standards of the colleges mentioned, are around 138, 123, and 159 per cent lower. If the Filipino standard is really representative it is certainly regrettable that such poor development and lung expansion exist and are allowed to continue. There is urgent need of remedial measures, and such measures should be instituted at once so that the normal expansion and capacity of the lungs of Filipino women may be increased by regular and properly conducted exercise.

It is, indeed, astonishing that the Filipino standard is much lower also than that of Chinese women. The Chinese standard shows the considerable difference of 117 per cent higher than the Philippine record. The vital-capacity standard of Chinese college women is given as 2,240 cubic centimeters, whereas that of Filipinos is 1,032 cubic centimeters. Even taking for granted that our figures for vital capacity in the work are too low due to lack of coöperation on the part of the subjects and to errors committed in recording the data, we believe that our finding cannot be more than 30 per cent lower than what might have resulted had careful measurements been taken. It seems obvious, therefore, that a low condition of vital capacity in Filipino women is actual.

Various reasons can be given in explanation of this regrettable condition, the most important of which is the lack of properly conducted exercise among Filipino women and their indisposition or indifference to physical exertion of any kind. Some of the other important reasons have already been given in the first part of this paper and, considered collectively, they explain the apparently existing ignorance of the proper method of breathing and, hence, the lack of good expansion of the lungs. It is certainly necessary that breathing exercises be regularly given in conjunction with other prescribed physical exercises in the public schools.

Weakened resistance of the lungs is the usual sequence of the existence of low vital capacity and will certainly promote the rapid course of pulmonary tuberculosis. The question of vital capacity is, indeed, of paramount importance in the Philippines, in regard to both young men and young women, because of its direct relation to the very serious question of high morbidity and mortality due to pulmonary tuberculosis among young Filipinos.

CHEST CIRCUMFERENCE

In this measurement also we believe there has been considerable error, either in the method of measurement or in the way of recording the data. Our findings do not seem to agree with our common observation, nor with the comparative standing of our group with the records of the college groups referred to. Our average chest circumference is 74.2 centimeters. There is presented a modal class of between 74 and 78 centimeters chest circumference in the group and the standard deviation found amounts to 3.66 centimeters.

The above record compared with the standard chest circumference of the women of the colleges referred to shows close similarity in the size of the chest. The comparative standing of the groups is shown in Table 22. (See also fig. 3.)

TABLE 22.—*Comparison of chest measurement of university women.*

	cm.
Wellesley	73.2
Oberlin	75.9
University of Nebraska	76.6
University of the Philippines	74.2

It is difficult to believe that the chest circumference of Filipino college women, as indicated in Table 22, is almost as great as that of American college women when their average vital capacity is less than half that of the American groups. We cannot explain this great difference between the chest circumference

and the lung contents; possibly greater development of the breast is natural in a tropical region, or perhaps the methods of recording vital capacity and of measuring the chest circumference in our group were irregular and incorrect. We learned that, in taking the chest circumference of the women of the University, the clothing was not removed and that many points essential to correct registration of data were taken for granted. In most cases due care was not observed to see that the tape was closely adapted to the thorax and mamma or that it bridged any part of the clothing. Therefore, indications point to the fact that our figures for chest circumference of the female group are too large. Therefore, the record and the standard derived from it as given here lose the greater part of their value and should be checked and verified later by new measurements.

It does not seem proper to report on the index of constitution, or robustness, of the female group under study, as this index depends upon the relation of stature, weight, and chest circumference. The last-mentioned measurement being more or less unreliable, the result of such a computation will necessarily be of little value.

SUMMARY OF FINDINGS IN THE FEMALE GROUP

Table 23 and fig. 3 present in concise manner our findings on the physical measurements of the female students of the University of the Philippines. Due allowance must be made in regard to the standard for the vital capacity and chest circumference, as already explained in previous paragraphs.

TABLE 23.—*Summary of measurements of Filipino university women.*

Measurement.	Mean.	Modal class.	Standard deviation.
Stature..... cm..	152.2	150- 156	4.69
Body weight..... kg..	43.2	35- 45	5.42
Vital capacity..... cc..	1,032.0	900-1,020	26.50
Chest circumference..... cm..	74.2	74- 78	3.66
Sitting height..... cm..	81.0	80- 84	2.88

The body-weight-per-unit stature in this group (per centimeter of stature) amounts to 287.1 grams. The standard of build is only 18.9 points.

For the purpose of comparative study Table 24 is given, which shows the physical standards of women students at some of the American colleges in comparison with those encountered in our work for women students of the University of the Philippines.

TABLE 24.—*Comparative measurements of university women.*

College group.	Stature.	Body Weight.	Weight-per-unit-stature.	Build.	Vital capacity.	Chest circumference.
	<i>cm.</i>	<i>kg.</i>	<i>g.</i>		<i>cc.</i>	<i>cc.</i>
Wellesley College.....	160.5	54.2	337.6	21.2	2,460	73.2
Oberlin College.....	159.8	51.0	319.1	20.2	2,310	75.9
University of Nebraska.....	160.0	51.4	321.2	20.1	2,680	76.6
Chinese College women.....	157.0	47.7	303.8	19.3	2,240	75.8
University of the Philippines.....	152.2	43.7	287.1	18.9	1,032	74.2

The figures for the Filipino college women are far below those of college women of America. Our records are even lower than are those of Chinese college women. As in the case of the male students, the female group also shows lower stature and lower body weight, and even much lower vital capacity than do American college women. It is noteworthy that the findings in both the male and the female groups of the Filipino university population, compared with the university population of other countries, demonstrate so low a standing. It would seem that certain general factors exist that influence and affect the physical condition and nutritional development of both groups. These factors have been discussed in the first part of this paper.

One additional point of importance that it is desired to mention here is the question of stimulating young people, and especially the young women, to devote more time and interest to out-door and open-air exercises. There exists great need of properly regulated and supervised exercise and out-door recreation for girls. If it is desired to improve the race in physical build from one generation to another it is very important and necessary that the country's future mothers be made physically fit, not only to ward off disease, but particularly to qualify them for the delicate task of bringing forth healthy and sound children and to nourish such children with the best natural feeding that a sound body constitution can offer.

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ILLUSTRATIONS

TEXT FIGURES

- FIG. 1.** Age frequency distribution of university students (University of the Philippines).
2. Graphic comparison of physical measurements of several university groups together with those of some oriental races (male).
 3. Graphic comparison of physical measurements of several college groups (female).

PHILIPPINE AND OTHER ORIENTAL DROSOPHILIDÆ

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Through the kindness of Prof. M. Bezzi I have been able to study a series of Philippine Drosophilidæ, collected chiefly by Prof. C. F. Baker. I have included in the present paper the results of a study of two other Oriental series in my collection, taken in Formosa by Dr. R. Takahashi and in India by Miss Eleanor D. Mason. Dr. O. Duda has recently published two papers dealing with the Palæarctic and Oriental members of the family, based on a study of much of the material in European museums.¹ These papers are so nearly complete that they must serve as the basis for any study of the Old World species. All that I shall do here is to present a few notes on species that I have seen, correlate the new species here described with Duda's account, add a few observations based on examination of some of the type material at the British Museum (which I visited in 1922), and introduce some modifications in the system, based chiefly on Malloch's work.²

The types of the new species based on Philippine material have been returned to Professor Bezzi. The types of *Drosophila* (*Spinulophila*) *immigrans formosana* var. nov. and of *D. takahashii* sp. nov. have been deposited in the American Museum of Natural History. Paratypes are in these two collections and in my own collection.

Genus AMIOTA Loew

Malloch (February, 1924) shows that *Amiota* Loew has priority over *Phortica* Schiner. I formerly placed both names as synonyms of *Stegana* Meigen, but Malloch shows that the genera are easily separable by the thornlike bristles on the undersurface of the costal vein near the wing tip. These thorns are present in

¹ Ann. Hist. Nat. Mus. Hung. 20 (December 24, 1923) 24-59; Arch. Naturg. 90A (June, 1924) 172-259.

² Proc. Linn. Soc. N. S. Wales 48 (December 14, 1923) 601-622; 49 (October 24, 1924) 348; Proc. Biol. Soc. Wash. 37. (February 21, 1924) 25-42.

Stegana (and also in *Leucophenga*) but absent in *Amiota*. Duda separates the two forms on the basis of the plane of the long axis of the eye (horizontal in *Stegana*, vertical in *Amiota*). This division does not correspond to that of Malloch, and seems to me less satisfactory, as it places in *Amiota* a number of species that appear to be much more naturally grouped with *Stegana*. The three new forms described here have a bearing on the ultimate treatment of the group; all of them key to Duda's subgenus *Eostegana* (Hendel) of *Amiota*, but two have costal spines while one has not, and the appearance of the forms is so diverse that it seems certain they should be given at least subgeneric distinction. Owing to lack of material I have not attempted here to elaborate any further classification than that into *Stegana* (with costal spines) and *Amiota* (without costal spines).

AMIOTA ALBODORSATA sp. nov.

Female.—Arista broken, but long branches still present above and below. Second orbital minute, inserted at same level as third. Front three times the width of an eye (as viewed from above), narrowed below. Greatest diameter of eye inclined about 45° from the vertical, nearly twice the diameter at right angles to it. Carina large, flat. Antennæ yellowish white, second joint grayish above. Face, front, and occiput white. Cheeks dark brown.

Mesonotum and scutellum white. The mesonotum is badly rubbed in the type; the scutellum is large, being more than half as long as the mesonotum. Pleuræ blackish brown, with a few small grayish markings. Legs dark brown.

Wings blackish, bent down at base as in most species of *Stegana*. Costa to apex of fourth vein, no thorns on its third section. Discal and second basal cells separated by a cross vein. Third vein at tip of wing; third and fourth veins not convergent apically. Second vein bent outward at apex, nearly straight basal to this curve. Last section of fifth vein 1.5 times length of posterior cross vein.

Abdomen yellow, each segment with a posterior black band. Egg guides yellowish brown, long, with black teeth below and a black point posteriorly.

Length, 2.25 millimeters.

Los Baños, Laguna Province, Luzon, Philippine Islands (*C. F. Baker*), type and only specimen.

This species resembles *Stegana* superficially; it might perhaps best be made the type of a new genus intermediate between *Stegana* and *Amiota*.

AMIOTA LEUCOPHENGOIDES sp. nov.

Male.—Arista with about twelve long branches above and eleven short ones below. Antennæ yellowish brown, face and frons yellow with whitish reflections, ocellar dot dark brown. Frons half the width of an eye, its sides nearly parallel. Anterior orbital broken in the type; middle orbital half the size of upper, twice as far from upper as from lower. Only one large vibrissa. Carina distinct, long but low. Cheeks very narrow. Eyes bare, vertical diameter twice horizontal.

Mesonotum and scutellum dark brown, somewhat pollinose posteriorly. Prescutellars large. Pleuræ dark brown, somewhat pollinose. Legs yellowish brown. Mesonotum black.

Wings straight, not broken at base as in typical *Stegana*. Discal and second basal cells separated by a cross vein. Costa reaches only to apex of third vein. No costal thorns such as are present in *Stegana*. Second, third, and fourth veins nearly straight, not sinuate or converging. Wings slightly smoky.

First abdominal segment yellow, with a broad black fascia on each side, the fasciæ not quite meeting in the middorsal line. Remaining abdominal segments shining black, each with a narrow yellow posterior border.

Length, 3 millimeters.

Batbatan Island, Philippine Islands (*R. C. McGregor*), type and only specimen.

This species might be placed in *Leucophenga* if one were disposed to emphasize the short costa rather than the basal cross vein.

Genus STEGANA Meigen**STEGANA BAKERI** sp. nov.

Arista with about seven branches above and four below. Carina absent. Antennæ brown, third joint blackish above. Face and mouth parts brown; frons brown, darker above. Frons parallel-sided, two-thirds the width of an eye. Lower and middle orbitals inserted at the same level, lower nearer midline of frons; upper orbital nearer to verticals than to two lower orbitals. Lower and middle orbitals nearly the same size. Postverticals minute. Cheeks very narrow. Vertical diameter of eye $1\frac{3}{4}$ horizontal diameter. Eyes bare.

Prescutellars well developed. Mesonotum reddish brown, subshining. Legs and pleuræ brownish yellow. A minute bristle near lower border of propleura.

Wings bent at base as in typical *Stegana*. Costa to apex of fourth vein; thorns on its underside just before apex of third

vein. Wings slightly smoky anteriorly. Second, third, and fourth veins not sinuate or convergent. Discal and second cells separate.

First abdominal segment yellow anteriorly, with a broad dull black band posterior to this, and a narrow whitish posterior margin. Second segment narrow, bright yellow, with no hairs or bristles. Third segment shining black with a narrow yellow anterior margin. Fourth segment shining black. Fifth segment yellow with black lateral margins.

Length, 3 millimeters.

Mount Maquiling, Luzon, Philippine Islands (*Baker*), type and only specimen.

The straight longitudinal veins of this species suggest *Amiota* or *Leucophenga*; but the characters given place it in *Stegana* as here defined.

LEUCOPHENGHA HALTEROPUNCTATA Duda.

Mount Maquiling and Los Baños, Laguna Province, Philippine Islands (*Baker*).

LEUCOPHENGHA ARGENTATA de Meijere.

Dapitan, Zamboanga Province, Mindanao, and Los Baños, Laguna Province, Philippine Islands (*Baker*).

LEUCOPHENGHA BEZZII sp. nov.

Arista with about nine branches above and four below. Antennæ yellow, third joint brown. Face, mouth parts, and frons brownish yellow. Frons parallel-sided, nearly as wide as an eye. Lower orbital inserted scarcely below middle one, but nearer midline. Middle orbital slightly larger than lower one. Upper orbital slightly nearer to inner vertical than to middle orbital. Postverticals minute. Carina absent. Cheeks very narrow.

Prescutellars well developed. Mesonotum and scutellum reddish brown, lightly pollinose. Pleuræ and legs yellow. Halteres whitish.

Wings smoky. Costa to apex of third vein. Tubercles on underside of costa just before apex of third vein.

First abdominal segment yellow, with a broad black fascia on each side, the fasciæ almost meeting in the middle line in one specimen. Second and third segments black, with yellow anterior border that is narrower in the median dorsal region. Fourth segment black. Fifth segment yellow, with black lateral margins.

Length, 2.5 millimeters.

Mount Maquiling, Luzon, Philippine Islands (*Baker*), type and paratype.

Genus ZAPRIONUS Duda

Subgenus PHORTICELLA Duda

Phorticella Duda (type, *Drosophila bistriata* de Meijere) was based on the small second orbital, four acrostichal rows, and absence of femoral tubercles. The two new species here described have new combinations of these characters, so that it seems most convenient to reduce *Phorticella* to a subgenus of *Zaprionus*, basing it on the small second orbital alone. Duda's definition of the genus *Zaprionus* should also be modified slightly so as to include the neotropical *Z. orbitalis* (Sturtevant), which has grayish orbits and no thoracic stripes. This species and *Z. bilineata* (Williston) from the West Indies, as well as *Z. multistriata* sp. nov., belong to the typical subgenus; *Z. bakeri* sp. nov. belongs to *Phorticella*; *Z. albicornis* Enderlein³ from Formosa and *Z. lineosa* (Walker) probably belong to the subgenus *Zaprionus*, but need to be checked.

ZAPRIONUS LINEOSA (Walker).⁴

From Macassar, Celebes. The type is a *Zaprionus*, with the usual brownish red color of the genus; four mesonotal white stripes (besides the notopleural stripes), that are barely united anteriorly into two; arista with three branches above and two below; face white.

ZAPRIONUS MULTISTRIATA sp. nov.

Female.—Arista with about four branches above and two below. Middle orbital very slightly smaller than upper, inserted halfway between upper and lower. Face prominent, carina large and flat. Frons yellowish red; orbits, median stripe, and lateral margins of ocellar triangle silvery white. Face, cheeks, and antennæ yellowish brown. Greatest width of cheeks (at lower posterior corner of head) about one-fourth height of eye. Eyes pilose. Only one prominent oral bristle.

Acrostichal hairs in six rows. Mesonotum reddish, with nine longitudinal white stripes, one between the two median acrostichal rows and four on each side as follows: One between the two outer acrostichal rows (that is, separated from the median stripe by two rows of acrostichal hairs); one outside the dorsocentral row and appearing continuous with the orbital

³ Deutsch. Ent. Zeit. (1922) 295.

⁴ Proc. Linn. Soc. London 4 (1860) 170, as *Notiphila*.

stripe and with the scutellar margin; an interrupted stripe appearing as a white margin to the humerus; and a stripe posterior to the suture. Scutellum reddish; with a median and two lateral white stripes that are continuous with the mesonotal stripes. Legs and pleuræ yellow. No femoral tubercles present.

Wings clear, veins brownish. Second, third, and fourth veins straight.

Abdomen dull yellowish brown.

Length, 2.5 millimeters.

Mount Maquilang, Luzon, Philippine Islands (*Baker 5260*), type and only specimen.

ZAPRIONUS (PHORTICELLA) BAKERI sp. nov.

Male.—Arista with about six branches above and four below. Middle orbital scarcely one-fourth the other two. Face prominent, carina large and flat. Face yellow. Frons yellowish red, orbits silvery white, forming white stripes which extend over the outer surfaces of second antennal joints. Only one prominent oral bristle. Greatest width of cheek about one-eighth greatest diameter of eye. Eyes pilose.

Acrostichal hairs in six rows. Mesonotum yellowish red, with four white longitudinal stripes, two on each side as follows: One just outside the dorsocentral row and appearing as a continuation of the orbital stripes, and a less distinct one just above the notopleural suture. On each side of the more-distinct white stripe is a darker brownish red stripe; the dorsocentral row of hairs is in the inner of these dark stripes. Scutellum yellowish red, bordered by white stripes that are continuations of the conspicuous mesonotal stripes and are also in turn margined by dark brownish red stripes. Pleuræ and legs yellow. No femoral tubercles.

Wings clear, veins brown. Last section of fifth vein $1\frac{2}{3}$ the length of posterior crossvein.

Abdomen yellowish brown, each hair and bristle arising from a dark brown spot.

Length, 2.5 millimeters.

Mount Maquilang, Luzon, Philippine Islands (*Baker 6230*), type and only specimen.

Genus **DROSOPHILA** Duda

Duda has separated *Drosophila* into a number of subgenera; and Malloch has suggested that some of his segregates from *Myco-drosophila* should also be placed under *Drosophila*. My opinion is that *Chaetodrosophilella* (see page 367) is also deserving of

only subgeneric rank. *Incisurifrons* Duda is a synonym of *Microdrosophila* Malloch. The three remaining subgenera present in the Oriental material before me were all first published in 1923 as genera, and genotypes have not been designated. We may select the following:

Hirtodrosophila, *H. longecrinita* Duda.

Paradrosophila, *Drosophila pictipennis* Kertesz.

Spinulophila, *S. signata* Duda.

In the case of *Spinulophila* only three forms were included, and two of these were described chiefly by stating their differences from *S. albomicans* Duda; but that species seems to have been undescribed at the time and therefore cannot become the genotype.

DROSOPHILA (CHAETODROSOPHILELLA) QUADRILINEATA de Meijere.

Mount Maquiling, Philippine Islands (*Baker*), one specimen. Recorded from Java and Annam. Duda gives the name as *Chaetodrosophila* in 1924; I have followed the original spelling.

DROSOPHILA (HIRTODROSOPHILA) LONGECRINITA Duda (typical form).

"Culasi, Panay. 5.18.18. Hillside forest at 800 meters. On fungus." (*McGregor*), seven specimens. Described from Formosa.

The six Oriental forms of the subgenus *Spinulophila* before me can be separated by the following key:

Key to six Oriental forms of Spinulophila Duda.

1. Cheeks (at lower posterior corner of head) one-fourth height of eye.. 2.
Cheeks one-sixth to one-tenth height of eye..... 3.
2. Males, basal tarsal joint of first leg with no strikingly long hairs.
D. (S.) *immigrans* Sturtevant.
Males, basal tarsal joint of first leg with strikingly long hairs.
D. (S.) *immigrans* var. *formosana* var. nov.
3. Thorax metallic; abdomen shining metallic black.
D. (S.) *monochaeta* sp. nov.
Thorax reddish; abdomen without bands; 3 millimeters long.
D. (S.) *rubra* sp. nov.
Thorax yellow, not reddish; abdomen with black bands; or fly less than 2 millimeters long..... 4.
4. Males with conspicuous silvering on front; less than 2 millimeters long; abdominal bands narrow or absent..... D. (S.) *nasuta* Lamb.
Faint silvering on front; more than 2 millimeters long; black abdominal bands distinct, broader in middorsal line....D. (S.) *balneorum* sp. nov.

DROSOPHILA (SPINULOPHILA) IMMIGRANS Sturtevant.

Drosophila tripunctata of authors, not of Loew.

Drosophila cilifemur VILLENEUVE.

Drosophila hypocausta OSTEN SACKEN?

I have the typical form of this species from Taihoku, Formosa (*R. Takahashi*), and females that are presumably typical (the variety *formosana* is not identifiable in females) from Kodai-kanal, Madras, India (*E. D. Mason*). The species is recorded from Europe, the Canary Islands, the United States, Costa Rica, Hawaii, Australia, and Formosa. *Drosophila hypocausta* Osten Sacken, which is perhaps an earlier name for the species, was described from the Philippine Islands.

DROSOPHILA (SPINULOPHILA) IMMIGRANS FORMOSANA var. nov.

Male.—Differs from typical *immigrans* only in the front tarsi. The short dense hairs of the two basal joints are less conspicuous than in the typical form, but there is a series of much longer recurved black hairs on the outer and anterior surfaces of all the joints of the front tarsi.

I am unable to separate the female from the typical form.

Taihoku, Formosa, March, 1924 (*Takahashi*), type and seven paratype males.

Duda also recognized this form from Formosa, but he failed to give it a name.

DROSOPHILA (SPINULOPHILA) MONOCHAETA sp. nov.

Arista with about eight branches above and five below. Carina prominent, large, flat. Middle orbital minute, but larger than the hairs anterior to it. Only one prominent oral bristle. Greatest width of cheek about one-sixth height of eye. Front reddish yellow; face, cheeks, and mouth parts yellow.

Mesonotum dark reddish brown, shining, with metallic bluish reflections posteriorly. Scutellum, pleuræ, and coxæ shining dark reddish brown. Legs yellow. Front femora somewhat swollen, bearing the usual row of small spines and, on the under-surface, only one bristle, which is much longer and stronger than the bristles usually present here.

Wings clear, except extreme base which is darkened. Only one spine at apex of first costal section. Costal index about 5, fourth vein index about 1.1, 5x index about 1, 4c index about 0.4.

Abdomen shining metallic black; two basal segments bluish, third to fifth more coppery.

Length, 2.5 millimeters.

Mount Maquiling, Luzon, Philippine Islands (*Baker 6224*), type and only specimen.

The metallic thorax and abdomen and the single long bristle on the undersurface of the front femur will identify this species.

DROSOPHILA (SPINULOPHILA) RUBRA sp. nov.

Male.—Arista with about eight branches above and four below. Carina large and flat. Second oral bristle nearly as large as first. Middle orbital not larger than the minute reclinate hairs anterior to it. Front and antennæ yellowish red. Face, cheeks, and mouth parts yellow. Greatest width of cheek about one-eighth height of eye.

Acrostichal hairs in eight rows. Mesonotum and scutellum dull yellowish red, pleuræ paler. Legs yellow. The usual row of spines present on front femora. Front tarsi without special hairs or bristles.

Wings clear, veins brown. Only one large bristle at apex of first section of costa. Costal index about 4, fourth vein index about 1.1, 5x index about 0.9, 4c index about 0.6.

Abdomen dull yellowish red.

Length, 3 millimeters.

Mount Maquiling, Luzon, Philippine Islands (*Baker*), type and only specimen.

The large size and red color should serve to identify this species easily.

DROSOPHILA (SPINULOPHILA) NASUTA Lamb.

Drosophila albomicans DUDA.

Taihoku, Formosa (*Takahashi*).

Recorded from the Seychelles and from Formosa. Lamb does not mention the femoral spines characteristic of *Spinulophila* in the description of *nasuta*; but I have seen the type, and such spines are present. The synonymy given here needs no further explanation.

DROSOPHILA (SPINULOPHILA) BALNEORUM sp. nov.

Male.—Arista with about seven branches above and five below. Carina large and flat. Second oral bristle nearly as large as first. Middle orbital one-fourth size of the other two. Greatest width of cheek one-sixth height of eye. Head yellowish brown, ocellar dot blackish, front with slight whitish reflection.

Mesonotum yellowish brown, slightly grayish pollinose. Scutellum and pleuræ brown. Legs brownish yellow, front femora darker. The usual row of spines on front femora; front tarsi plain.

Only one large bristle at apex of first costal section. Wings clear, cross veins faintly clouded. Costal index 3.5; fourth vein index 1.3; 5x index 1; 4c index 1.7.

Abdomen yellowish brown, each segment with a dark posterior band.

Length, 2.5 millimeters.

The females before me have paler legs and long slender egg guides.

Los Baños, Laguna Province, Luzon (*Baker 984*), type. Los Baños, Mount Maquiling, Philippine Islands (*Baker*) paratypes, three females.

DROSOPHILA (PARADROSOPHILA) LURIDA Walker.

Discomyza punctipennis v. d. WULP.

Mount Maquiling, Luzon, Philippine Islands (*Baker*), two specimens.

I have examined the type (from Macassar, Celebes), and a Javan specimen determined by de Meijere. These agree with each other and with the Philippine specimens.

DROSOPHILA (PARADROSOPHILA) ACUTA sp. nov.

Female.—Arista with about ten branches above and four below. Second oral nearly as long as first. Middle orbital one-third other two. Carina large, broad, and flat. Second antennal joint with an unusually long and heavy bristle on its inner surface. Front dark reddish brown, a silvery spot on the occiput on each side of the ocellar region. Face black, cheeks dark brown. Greatest width of cheek about one-fourth height of eye. Eyes pilose.

Prescutellars large. Acrostichal hairs in at least eight rows. Thorax dull black. Legs brown, front femora blackish, all tarsi yellowish. Halteres white.

Wings clear, blackish at base. Costal index about 1.8; fourth vein index about 1.8; 5x index about 0.9; 4c index about 1.4.

Abdomen dull black. Egg guides brown, slender, drawn out into an acute tip.

Length, 2.7 millimeters.

Mount Maquiling, Luzon, Philippine Islands (*Baker*), type and only specimen.

DROSOPHILA MELANOGASTER Meigen.

Drosophila ampelophila LOEW.

Nungambaukam, Madras, India (*Mason*).

I also have specimens from Peking, China, and from Fukuoka and Shinano, Japan. The species is cosmopolitan. Duda argues that Loew's name should be used, but I am not convinced.

DROSOPHILA ANANASSAE Doleschall.

Nungambaukam, Madras, India (*Mason*), many specimens of both sexes. One of the females has an egg just protruding from the ovipositor; this egg has two anterior filaments.

The species is recorded from Formosa, Java, Sumatra, and New Guinea.

DROSOPHILA TAKAHASHII sp. nov.

Male.—Arista with about five branches above and four below. Second oral nearly as long as first. Middle orbital one-fourth the other two. Carina low, flat. Front, antennæ, face, and cheeks brownish yellow. Greatest width of cheek about one-tenth height of eye. Eyes pilose.

Acrostichal hairs in eight rows; no prescutellars. Mesonotum and scutellum yellowish red, subshining. Pleuræ and legs yellow. On the undersurface of the basal joint of the front tarsi are short stiff black bristles, arranged in six short transverse rows; two such rows also on the undersurface of the second joint of the front tarsi.

Wings clear. Costal index about 2.3; fourth vein index about 2.6; 5x index about 2; 4c index about 1.3.

Abdomen shining black, each of the three basal segments with a basal yellowish band.

Length, 2 millimeters.

The females agree with the above description, except that the front tarsi are plain and the fourth abdominal segment has a basal yellow band.

Taihoku, Formosa, March, 1924 (*Takahashi*), type and nineteen paratypes.

The species resembles *D. melanogaster* and *D. ananassae*. The cheeks are narrower in *takahashii*, and the structure of the male front tarsi is different. In *melanogaster* the small black bristles are confined to one diagonal row on the inner dorsal surface of the basal joint; in *ananassae* there are several transverse rows on the ventral surface, but the bristles are yellowish instead of black.

DROSOPHILA MONTIUM de Meijere var. **ATROPYGA** Duda.

Nungambaukam, Madras, India (*Mason*), one male.

DROSOPHILA TRISTIPENNIS Duda.

Nungambaukam, Madras, India (*Mason*), one male.

DROSOPHILA HYDEI Sturtevant.

Taihoku, Formosa, March, 1924 (*Takahashi*), one specimen.

Recorded by Malloch from Sydney, Australia, and occurs from Massachusetts to California, Panama, and Porto Rico. It is distinguishable from *D. repleta* in that it has smaller eyes and no lateral pale spots on the dark abdominal bands.

DROSOPHILA HIRTISCUTELLATA sp. nov.

Male.—Arista with five branches above and three below. Only one prominent oral bristle. Middle orbital one-third the other two. Head dark brown. Greatest width of cheek one-sixth height of eye. Eyes pilose.

Thorax and legs dark dull brown, tarsi yellowish. Margin of scutellum with a few hairs; about three in front of anterior scutellar bristle and three behind it.

Wings clear. Costal index about 2; fourth vein index about 2; 5x index about 1.3; 4c index about 1.2.

Basal abdominal segment brown, with dark fascia on each side; remaining segments dark dull brown, each with a narrow apical border that is paler.

Length, 2.2 millimeters.

Mount Maquilung, Luzon, Philippine Islands (*Baker*), type and only specimen.

The hairs on the scutellum will serve to identify this species. The character is not known in any other member of the family, if one excludes the genus *Curtonotum* and its relatives from the Drosophilidæ (as I am inclined to do).

DROSOPHILA ELONGATA sp. nov.

Male.—Arista with about six branches above and three below. Only one prominent oral bristle. Middle orbital hairlike. Carina low, broad, flat. Front shining yellow. Face whitish. Antennæ and cheeks yellow. Greatest width of cheek one-sixth height of eye. Eyes bare. Head bristles all brown.

Acrostichal hairs in eight rows. Prescutellar region damaged in the type. Mesonotum and scutellum shining yellow. Pleuræ and legs yellow. First tarsal joint of front leg as long as the four distal joints. Thoracic bristles and hairs all yellowish.

Costal, marginal, and apex of submarginal cells black; wings otherwise clear. Distal costal incision well marked. Costal index about 1.5; 5x index about 1.1; 4c index about 1.

Abdomen elongate; shining yellow above, shining black laterally, dull yellow below; bristles yellow.

Length, 2.7 millimeters.

Los Baños, Laguna Province, Luzon, Philippine Islands (*Baker*), type and only specimen.

This species is scarcely a *Drosophila*, the bare eyes and elongate abdomen being distinctly out of place here. Perhaps it is a member of one of the groups placed by Duda near *Mycodrosophila*, but I am unable to satisfy myself as to the status of these forms without more material than is now available. Malloch has previously expressed doubts as to the treatment that should be accorded to this general group.

NOTES ON TYPE SPECIMENS OF ORIENTAL DROSOPHILIDÆ DESCRIBED
BY WALKER

DROSOPHILA FINIGUTTA Walker.

Drosophila finigutta WALKER, Proc. Linn. Soc. 3 (1859) 126, Aroe.

This is a sapromyzid.

DROSOPHILA ILLATA Walker.

Drosophila illata WALKER, Proc. Linn. Soc. 4 (1860) 168, Macassar, Celebes.

This is a *Drosophila*, of the *melanogaster* group; but the type is so badly damaged that specific identification will probably not be possible.

DROSOPHILA LATERALIS Walker.

Drosophila rudis WALKER, Proc. Linn. Soc. 4 (1860) 169, Macassar, Celebes.

A *Leucophenga*, apparently near *L. salatigae* de Meijere.

DROSOPHILA LURIDA Walker.

Drosophila lateralis WALKER, Proc. Linn. Soc. 4 (1860) 169, Macassar, Celebes.

See above, under subgenus *Paradrosophila*.

DROSOPHILA MELANOSPILA Walker.

Drosophila melanospila WALKER, Proc. Linn. Soc. 3 (1859) 126, Aroe.

This is a sapromyzid.

DROSOPHILA PINGUIS Walker.

Drosophila pinguis WALKER, Proc. Linn. Soc. 8 (1865) 168, New Guinea.

This is a sapromyzid.

DROSOPHILA RUDIS Walker.

Drosophila rudis WALKER, Proc. Linn. Soc. 4 (1860) 168, Macassar, Celebes.

A *Leucophenga*, apparently not recognized since Walker's time. Walker's description of the wing pattern is accurate and should serve to identify the species. The palpi are yellow.

DROSOPHILA SOLENNIS Walker.

Drosophila solennis WALKER, Proc. Linn. Soc. 4 (1860) 168, Macassar, Celebes.

This is a true *Drosophila*. I have seen no other specimens agreeing with it, but Duda's table suggests that it may be the same as *D. obscuricornis* (de Meijere). The species suggests *D. immigrans*, but lacks the femoral spines of *Spinulophila*. The middle orbital is nearly two-thirds the length of the upper one; second oral nearly as long as first; carina large and flat; acrostichal hairs in eight rows; four dark stripes on mesonotum, the outer ones interrupted; costal index about 3.6, fourth vein index about 1.5, 5x index about 1.1, 4c index about 0.7; abdomen yellow, each segment with a broad posterior dark brown band that is broader in the median dorsal line.

NOTIPHILA LINEOSA Walker.

Notiphila lineosa WALKER, Proc. Linn. Soc. 4 (1860) 170, Macassar, Celebes.

This is a *Zaprionus*, and is included in the discussion of that genus presented in this paper.

SCIOMYZA LEUCOMELANA Walker.

Sciomyza leucomelana WALKER, Proc. Linn. Soc. 4 (1860) 144, Macassar, Celebes.

As was pointed out to me by Maj. E. E. Austen, this belongs to the genus *Stegana*, as here understood.

BIOLOGY OF THE LARGE PHILIPPINE FOREST SCORPION

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FOUR PLATES

The large forest scorpion *Palamnaeus longimanus* Herbst is rather common on certain islands of the Philippines but, strangely enough, it seems to be absent on other islands of the group, particularly Luzon. During the last twenty years certainly sufficient collecting has been carried on in Luzon to have revealed this species if it were present at all. Our records show the species from various localities in Mindanao, Palawan and, lately, from Tawitawi in the Sulu group.

Although several authors have on various occasions identified Mindanao specimens of this large forest scorpion as *P. longimanus*, the correctness of this identification seems open to doubt, due to the following facts. In the course of the work on the biology of these scorpions it occurred to me that even in the comparatively young stage it should be possible to distinguish males from females, since in *longimanus* the male has rather long and slender chelipeds and in the female they are much stouter, shorter, and broader. Since I was unable to find any appreciable difference in this respect in the different individuals which I raised, I examined over one hundred fifty specimens of alcoholic material in our collection, and to my astonishment found not a single specimen that could be recognized as male by the long chelipeds.

A few Mindanao specimens were examined by Professor Borelli of Turin, and determined by him as *P. longimanus* females and, in a letter recently received from him, he states, "the females of *P. longimanus* and of *P. oatesii* are very difficult to distinguish."

From the above-mentioned facts, I am inclined to the belief that the large Mindanao forest scorpion may possibly not be *P. longimanus* Herbst but *P. oatesii* Pocock or a subspecies of the latter since in *oatesii* the two sexes, according to the descrip-

tion, are very much alike, particularly with reference to size and form of the chelipeds. The question can only be solved by anatomical examination of freshly killed material. Since I have at the present time none available, this question must be left open for the present.

The Philippine forest scorpions are usually found in old or virgin forest under the loose bark of dead standing trees, under decaying trunks of trees and logs, or in cavities of rotten stumps located in the jungle, mostly in rather humid and damp places. In most instances I found two or more individuals together in one place, either two adults (which I assumed to be a male and a female) or, more commonly, one adult female and from five to nine young ones. The latter in every instance had gone through at least the third molt. It would seem that in nature the pregnant female selects the most secluded and protected places for giving birth to her offspring, and probably remains in such places until the young have passed the early stages of life. Later, probably impelled by relative scarcity of food, the mother scorpion, followed by her young ones, seeks other hiding places, such as mentioned above, in which they are most commonly found. It is probable that, during the early stages, a relatively large number of the young scorpions fall prey to their enemies. So far I have been unable to ascertain what these enemies are, but very strongly suspect that large geckos, toads, and certain shrews attack young scorpions.

The food of the forest scorpion here dealt with consists of such insects as are found or seek shelter in the places indicated above. In other words, scorpions do not go to seek their food but the insects which serve as their food come to the scorpion's lair for the purpose of hiding. On several occasions I found in a scorpion cavity under a rotten log a few fragments of wings and legs of the large wood cockroach. Various species of *Blattidæ* seem to be the favored food of this species of scorpion, as I was able to prove in my breeding experiments described later. Of course, other insects which trespass within the bounds of the scorpion's home, such as certain crickets (*Gryllidæ*), earwigs (*Forficulidæ*), and certain larvæ of *Coleoptera*, are also taken at times, but the principal food consists of *Blattidæ*. From actual observation over a long period of time I can safely state that the amount of food taken by a scorpion depends on the supply that nature provides. If the supply of the proper kind of food is plentiful, at least with reference to the species dealt

with herein, the quantity consumed by the scorpion is relatively very large, contrary to the observations of J. H. Fabre.¹

On June 15, 1925, I received a large adult living scorpion from Malangas, Mindanao. From its appearance, I concluded that it was probably a pregnant female. Although it had received rather rough treatment on the voyage to Manila, it appeared in healthy condition and fighting spirits. Since so little is known concerning the biology of the scorpions of this region, I seized this opportunity to work out the life history, although somewhat hesitant on recalling the writings of Fabre² and his assertion that the life history of the European species is at least five years.

The scorpion was placed in a square museum jar, 8 by 9 by 9 inches. In the bottom of the jar about 1 inch of fine, slightly moist river sand was put and, on top of this, several pieces of convexly curved bark were placed so as to provide a hiding place for the scorpion. The scorpion during the first few days was mostly in hiding during the daytime under the bark in a resting position. The legs and chelipeds were drawn up close to the body and the tail curved flat over the back. Toward evening and at night it would wander around and investigate its surroundings, at times trying to crawl up the sides of the glass container. Very soon I noticed that the scorpion very much disliked the bright daylight and especially the direct sunlight, and always sought the darkest spot of the jar. Accordingly, the jar was placed in a rather dark corner of my work room. On several occasions during the daytime I noticed that the scorpion was rather restless, reaching about with its chelipeds. Since the glass jar was only covered with fine wire gauze, the sand in the jar soon became dry. For that reason, I was inclined to ascribe the restlessness of the scorpion to thirst and tried sprinkling it with water. My supposition proved absolutely correct. The scorpion had to be given a certain amount of water every day, and it was astonishing how long and what large amounts of water this creature would drink. The process of drinking was mostly accomplished by the mandibles taking up the water from grooves in the bark on which the scorpion was sitting at the time, or the mandibles would take up drops of water which were scattered over the different reachable parts

¹ *The Life of the Scorpion* (English edition) 1923.

² *Op. cit.* page 47.

of its legs. On several other occasions I noticed a very peculiar way of taking up water, absolutely the same as the method I have observed among certain crabs. The scorpion would sip with the mandibles water that had accumulated between the chelæ; that is, it would move the latter close to the mandibles in the way a man holds a glass in his hand and brings it toward his mouth. The scorpion, even when apparently in a sleepy condition and resting quietly in the jar, was at all times very alert; any unusual whiff of air, a slight knock against the jar, or the touching of the bark in the jar would instantly arouse it to assume a combative attitude. The legs would be more spread, the chelipeds would be held with the chelæ in a half-open position, forward or directed slightly upward, and the tail would be raised ready to strike. It is astonishing how quickly it can turn about if the need arises.

The question of food caused considerable worry at first. I tried out various kinds of insects, such as small Locustidæ, Acrididæ, Gryllidæ, and Blattidæ. Besides insects, I also offered specimens of a small species of snail, which is usually found under moist bark, and some earthworms. The scorpion manifested absolutely no gustatory interest in the last-mentioned creatures; but, if an earthworm happened to come too close, it would squeeze the worm with its chelæ, simply as a means of getting rid of the undesirable visitor and starting it to move in another direction.

Of the various insects mentioned above which I offered as food to the scorpion in captivity, only certain small Gryllidæ and all species of Blattidæ were taken by it freely and of its own accord. As mentioned before, the food of the scorpion consists of such insects which, as a matter of chance, come within its reach, and it seems almost as if its chelæ were especially constructed for or particularly adapted to holding such flat insects as Blattidæ. The hungry scorpion is very alert and a cockroach passing over its body or in front near the chelipeds, apparently not being aware of its enemy, is easily caught. It is astonishing to see how quickly a scorpion is able to catch a large cockroach such as *Rhyparobia maderae* Fabricius or *Periplaneta americana* Linnæus, and hold it somewhat above the ground thus preventing the struggling cockroach from getting a foothold by which it would be able to exert more strength in the efforts to free itself from its enemy. During the long period of observation, I have never seen the scorpion use its poisonous stinger at any time in procuring or subduing the

insects serving as its food. I believe the poisonous stinger is used only as a defensive weapon against its enemies. Furthermore, the stinger is certainly not at all well adapted for use on insects, since it is not strong enough to penetrate chitin of ordinary thickness and will glance off readily.

On July 25, at 7 o'clock in the morning, I observed that the scorpion had during the previous night given birth to eleven young ones. Eight of the latter were located on the back of the mother, and three others were suspended from or clinging to the forelegs on the underside of the body.

While I was watching the scorpion, which held its body in a peculiar position, somewhat raised and bent or curved in the middle into a convex shape but with the chelipeds drawn up close to the body (in an aspect from which it appeared as if she exerted some pressure), I noticed that another young scorpion was just in the act of being born. This young one was coming out of the vaginal orifice in the shape of an elongate white drop. No legs or other appendages were visible to me at the time. Unfortunately, I had great difficulty in seeing clearly what was going on through the sides of the thick glass and I did not dare disturb the mother while in the process of giving birth. At any rate, from my short observation I am unable to confirm or to disprove the assertion made by Fabre that the young scorpions are born in a kind of chorion similar to that enveloping certain mammals, and that the female ruptures the sac and liberates the young ones. After a very short time I noticed that the last-born young scorpion was resting on the apical parts of the bent-under forelegs of the mother, slowly making its way up the leg and the sides of her body. The newly born seem to be extremely helpless and frail creatures. During the act of birth I observed also that the pectines were carried in a vertical position pointing downward, seemingly to serve as holders or braces. The young scorpions are extremely sluggish, plump, and fat looking, and very pale, glossy, creamy white. About half an hour after being born the eyes of the young (that is, the two discal eyes as well as the 2×3 frontal-marginal eyes) turned blackish. At about 9 o'clock in the morning all of the young were located on the back of the mother. It took, by actual observation, at least two hours for the last-born young one to locate itself at the final resting place on the back of the mother. During that same day I observed the mother scorpion and her young numerous times; mostly she was in a resting position, but at the same time she was un-

usually nervous and alert to the slightest whiff of air or the slightest disturbance. In the afternoon a photograph of the mother and her young ones was taken; the result was not very favorable owing to the nervousness of the mother, but a photograph of a young one which I had carefully isolated from the mother was successful and is here reproduced as Plate 1, fig. 2. Early in the morning of July 26, to my great astonishment I noticed that the female scorpion had given birth to still more young ones during the previous night, the additional number being twenty-two, since under difficulties I was able to count thirty-four young scorpions in all. Although the mode of giving birth to the young at intervals, in this case in two distinct periods with an intervening rest time of at least ten hours, seems strange to me, similar occurrences are rather common among mammals. Nevertheless, I now look upon my findings as probably due to abnormal environmental conditions, at least pending further observation and verification. The female scorpion, until a few days before giving birth, was during most of the daytime hiding under a piece of bark which formed a flattish cavity and which she almost filled. A day or two previous to delivery she changed her habitat, sitting on top of the bark. The cavity under which she had been hiding was entirely too small for her to have gone through the act of giving birth and the change was instinctively made for that reason. Furthermore, in nature, the female scorpion probably goes through this act in a well-protected and sufficiently large cavity, located in a hollow tree or some other obscure place. In such locality it seems reasonable to suppose that the scorpion, once having commenced giving birth, would continue until all had come forth; but, under the artificial environment, this scorpion probably started during the night, while sitting on top of the bark, and when daylight came interrupted the act until darkness set in again during which delivery was completed. Although my interpretation is theoretical, I consider it a logical explanation of the above facts. The mother scorpion with her litter of thirty-four young all bunched and clustered closely over her back is a truly remarkable sight; indeed, may this not account for her nervousness, particularly since the young cover up her discal eyes and sometimes the frontal lateral eyes as well? On the same day I succeeded in taking the excellent photographs shown in Plate 1, fig. 1 (dorsal view) and Plate 4, fig. 2 (ateral view), both natural size. On the same day, I also noticed that some of the

young ones, probably the ones born the previous day, were slightly darker than the rest. On July 28 the young ones appeared smaller and distinctly darker creamy white than on the previous day; in the afternoon of the 28th the color was still more noticeably darker grayish cream and the young appeared slightly shriveled (see Plate 1, fig. 3, photograph taken on July 28) and not so roundish and plump as on the preceding day. On the succeeding days the young ones became still more pale grayish and at all times were almost motionless. Even when I blew lightly upon them they hardly reacted. During all of this time the mother scorpion was not observed to feed during the daytime as she had done prior to giving birth, but later she drank water on several occasions.

The water was sprinkled on the bark on which the mother scorpion was sitting. She was very much annoyed when a few drops of water fell on her back, which caused her as well as the young to show decided discomfort.

On August 3, or eight days after birth, in the early forenoon, I observed that most of the young ones were going through some very lively contortions, bending and wriggling on the back of the mother, and soon I noticed that they were molting for the first time. It is astonishing how the form of the young scorpions had changed from that of the first stage. They appeared much longer and larger, and their chelipeds, legs, and tails were shaped more like those of the mother scorpion; but they were really smaller than when newly born. Plate 1, fig. 4, shows a young scorpion, natural size, one day after the first molt. Its color shortly after molting was very pale glossy gray, which turned slightly darker as the chitin hardened, except the last tail segment (the vesicle), which was whitish. All of the thirty-three young scorpions (one had been placed in alcohol previously) passed through the first molt within twenty-four hours.

Furthermore, the young ones had become much livelier; frequently I observed them rather restlessly changing their positions on the back of the mother, in doing so wriggling their tails freely. Some of the first exuviae of the young could be seen adhering here and there to the back of the mother. The fine white skins appear as irregularly torn fragments and seemingly serve the young ones as a medium for hanging on to, or catching hold of, the otherwise rather smooth back of the mother. On August 5 I observed that several of the young scorpions were trying to push each other off, and several actually left the back

of the mother and were trying to hide underneath her. On August 6, early in the morning, I observed that more than half of the young ones were sitting in front and around the mother. After the first molting of the young ones I placed several live medium-sized cockroaches in the jar with the scorpions. Some of them were undoubtedly eaten by the mother scorpion during the night; I suspect that the young ones also took part, but I did not actually see them do so. The young scorpions during the second instar do not seem to grow to any appreciable degree. A very noticeable fact during the second instar is that the different individuals are still remarkably uniform in size. During the night from August 9 to 10 more than half of the young scorpions molted the second time and the last one molted on August 12. The skins, or exuviae, of the second molt were found scattered about in the jar, some freely exposed, some under the bark. In order to demonstrate the individual differences, I have reproduced in natural size exuviae of the second molt of two individuals, on Plate 1, figs. 5 and 6. By comparing these with fig. 4, it will be seen that fig. 4 shows the hands, or chelipeds, to be slightly larger. This is due to the fact that the scorpion reproduced as fig. 4 was photographed only one day after the first molt and before it had fully hardened; in other words, as the chitin hardens it also shrinks somewhat. In the third instar, after the specimens were fully hardened the young scorpions were darker, grayish brownish; only the vesicle was still grayish white. Up to August 11, or seventeen days after birth, a few of the young scorpions were still sitting on the back of the mother, but from August 12 none of them continued the practice. All of them were by that time more or less scattered about in the jar, some sitting under or around the mother, others hiding under pieces of bark. The young ones by their actions appeared less timid than before. From the last-mentioned date on I observed the young ones many times in the act of feeding in company with the mother during the daytime. The feeding procedure was usually as follows:

Several adult cockroaches were thrown into the jar containing the scorpions. The mother scorpion, who always seemed to be on the qui vive, quickly turned about and grabbed one of the cockroaches with one of her chelipeds, squeezing it at the same time, and then passed it to the other cheliped, and so on back and forth two or three times, until the roach stopped its violent kicking. After a short interval the scorpion mother

proceeded to tear away small pieces of the cockroach with her mandibles and eat them. The cockroach was not dead by any means but struggled more or less during the process. The young scorpions that had been sitting near the old one, as well as others which were hiding under the bark, had been aroused by the disturbance caused by the rushing cockroaches as well as by the moving about of the mother. They soon learned the cause of all the commotion and soon gathered on and about the prey the mother was holding and joined in the meal, particularly after the mother had removed the greater part of the elytra of the roach and thus had exposed the more juicy part of its abdomen. The mother scorpion would stop eating at intervals for several minutes as if to give the young ones a chance to take their meal. One of the most remarkable facts concerning the mother scorpion I noticed many times was the following: If several cockroaches or other insects were rushing about in the jar, sometimes running over or under the mother, the latter invariably noticed the difference between an insect or other strange object touching her and the contact of her own young. She would quickly turn upon the touch of even a small cockroach running over her but would pay no attention to her own young doing the same thing. The latter, particularly during feeding time, climbed over her back, or sat upon the carapace in variable numbers so that her eyes were covered up. The sensitive hairs present on many parts of her body, chelipeds, legs, and tail, seem to be very efficient organs of touch, capable of noting the difference between her own young and strange objects. The eyesight seems to be of secondary importance, or is used mainly in respect to large objects. The scorpions were always supplied with a liberal number of young and adult cockroaches and some crickets, although the latter were few in number since it was rather difficult to obtain them. Every two days water was sprinkled in the jar so that the sand was kept slightly moist. Under the described conditions the young scorpions were thriving very well and they grew considerably stouter. During the latter days of August I noticed that the young scorpions did not consume as many cockroaches as they had before and that they had become more sluggish. During the night from September 2 to 3, three scorpions molted for the third time, another molted at noon of the 3d, many more molted on September 4, six on the 8th, three on the 12th, and the last one passed the third molt on the 26th. Shortly before and during the process of molting, and for several days

after each molt, the scorpions were rather sensitive and irritable. During the third molt one scorpion died, on September 5, and two on September 9; in the process of molting the specimens were unable to cast off the old skin and were found dead. The last two dead scorpions I found partially buried in the sand, from which fact I concluded that they were trying to get into a moister place for the purpose of molting since all the other scorpions also showed a preference during molting for a fairly moist place in the jar, a cavity under a piece of bark. It seems that during molting the conditions of humidity must be absolutely right, so that the skin can be cast off readily. If the surroundings are too wet or too dry, molting will not proceed normally. Furthermore, it seems that the molting process takes place whenever the physical development has reached a certain stage. When that stage has been reached, and the conditions are not what they should be, the process cannot be delayed until later but must take place; if this is not possible the scorpion must perish. The molting process seems to be identical to that in the grapsoid crabs. The skin is ruptured around the anterior and lateral edges of the carapace due to internal pressure. By very strenuous contortions and exertions, the mandibles are first extracted, later the chelipeds follow. By still more strenuous efforts the anterior part of the body pushes forward and partially out of the old skin, then the legs are pulled out, and finally the whole scorpion wriggles out. The newly molted creature is extremely soft and very pale semi-translucent, grayish pinkish in color. It assumes a resting position after the molt, and if not molested remains in that position from one to several days, until it has hardened somewhat. On Plate 2, figs. 1 to 3, I have shown three exuviae of the third molt of three individuals, in order to demonstrate the relative differences between them. Up to the third molt I had killed, intentionally, eight of the young scorpions in different stages, and preserved them in alcohol for further study. Three scorpions died or were killed during the fourth instar, so that there remained a total of twenty-one. Since the original jar had become rather crowded, and as I noticed that the young scorpions evidently preferred to have their surroundings more moist and humid, I separated all the young ones from the mother scorpion, placed them in several jars containing also moist sand at the bottom and a large piece of bark for hiding, and covered the jars with glass plates in order that the air in the jars was

always very humid and laden with moisture. The young scorpions I fed mostly with small to half-grown cockroaches; at times I injured adults of the latter slightly by squeezing them, so that the scorpions were able to subdue them more quickly. Under the newly modified conditions all of the scorpions were apparently well and were perfectly able to secure the food necessary for their maintenance. From October 4 to 6, five specimens molted for the fourth time. Seven other individuals passed the fourth molt between October 8 and 12. The rest of the young ones molted for the fourth time at very irregular intervals, the last one on March 10, 1926.

On Plate 2, figs. 4 and 5, are shown the fourth exuviae of two specimens, demonstrating the slight individual differences in size.

During the period of the third molt, and in a more marked degree during the fourth instar, and still more so thereafter, it is clearly to be seen that the growth of the various individuals becomes more and more irregular as they generally advance in age. This fact is better demonstrated in Table 1.

TABLE 1.—*Showing dates of molting of young scorpions born on July 25 to 26, 1925.*

FIRST MOLT.

Date.	Number of specimens that molted.	Remarks.
1925 August 3.....	33	Length of first instar, eight days. One specimen killed.

SECOND MOLT.

1925 August 9 to 12.....	32	Minimum length of second instar, 6 days. Maximum length of second instar, 9 days. Eight specimens died or were killed.
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THIRD MOLT.

1925		
September 3.....	4	Minimum length of third instar, 25 days.
September 4.....	10	Maximum length of third instar, 45 days.
September 8.....	6	One placed in alcohol and two died.
September 11.....	3	
September 26.....	1	

TABLE 1.—*Showing dates of molting of young scorpions born on July 25 to 26, 1925—Continued.*

FOURTH MOLT.

Date.	Number of specimens that molted.	Remarks.
1925		
October 4.....	3	Minimum length of fourth instar, 31 days.
October 6.....	2	Maximum length of fourth instar, 165 days.
October 12.....	7	One died.
November 14.....	2	
November 22.....	1	
November 28.....	1	
December 4.....	1	
1926		
January 10.....	1	
January 28.....	1	
February 6.....	1	
March 10.....	1	

FIFTH MOLT.

1926		
January 21.....	6	Fifth instar approximately 114 days.
January 24.....	2	One of January 21 placed in alcohol; three died.
February 6.....	4	
February 8.....	1	
February 15.....	1	
February 24.....	1	
March 10.....	1	
March 18.....	1	
March 30.....	1	
April 7.....	1	
April 24.....	1	

SIXTH MOLT.

1926		
April 10.....	1	Sixth instar approximately 75 days.
April 13.....	2	Three died.
April 14.....	1	
April 17.....	1	
April 19.....	1	
April 25.....	2	
May 5.....	1	
May 12.....	1	
May 21.....	1	
June 27.....	1	
July 26.....	1	
July 30.....	2	
September 2.....	1	

TABLE 1.—*Showing dates of molting of young scorpions born on July 25 to 26, 1925—Continued.*

SEVENTH MOLT.*

Date.	Number of specimens that molted.	Remarks.
1926		
July 5.....	1	Seventh instar approximately 85 days.
September 1.....	1	The scorpion that molted on September 1 had one cheliped injured during molting and died.
September 11.....	1	
September 12.....	2	Another of September 11 died during molting.
September 22.....	1	
September 25.....	1	
September 26.....	1	
November 1.....	1	

* On February 8, 1927, there are eleven scorpions still alive and healthy, seven of which are adults and four are still in the seventh instar.

Table 1 shows clearly that thirty-three young scorpions (one I killed intentionally for preservation in alcohol) all molted at about the same time, on August 3, the first instar lasting eight days. The second molt of thirty-two specimens (one more had been killed) extended over a period of three days. The third molt of twenty-four specimens extended over a period of twenty-three days. The fourth molt of twenty-one specimens extended over a period of one hundred sixty-five days. The fifth instar of twenty specimens can be calculated at approximately one hundred fourteen days. The sixth instar can be considered at seventy-five days. On July 5, 1925, one individual molted for the seventh time and thus reached the adult stage. Eight other individuals molted for the last time on the dates given in Table 1. The newly molted adult is very pale reddish or brownish gray, becoming darker from day to day. Fifteen days after attaining the adult stage, the color is dark castaneous. As the individual grows older the color becomes more piceous until it is black. The newly molted adult was extremely irritable and at the slightest provocation was ready to fight. About eight days after reaching the adult stage it was sufficiently hardened to take food. In the method of feeding on a cockroach, it acted somewhat differently from its mother which I had observed many times. The cockroach was not eaten up entirely but was chewed up into small fragments and the juice extracted. Then the fragments were left in the shape of an

irregular roundish lump of about half or three-quarters of a centimeter in diameter. Plate 3, fig. 1, shows a specimen a few days before the seventh molt, and fig. 2, the exuvia of the seventh molt.

Another noteworthy fact, well demonstrated by Table 1, is the extreme irregularity of growth of the young scorpions during the fourth and following instars, as manifested by the respective molts. The young were separated from the mother on September 3. Up to that time the food was mostly secured and killed for them by the mother, but after the last-mentioned date all of the young ones had to shift for themselves. Certain individuals, which for one reason or another had attained greater strength, were better fitted for the struggle for existence. Thus they were able to obtain the best and largest amount of food more easily. Furthermore, they were able to retain the lead once obtained and, in fact, increased the latter as they grew older.

The experiments described in this paper demonstrate that one specimen of this species of scorpion reached the adult stage in three hundred forty-five days, and that eight specimens reached the adult stage in from four hundred three to four hundred sixty-four days, while four specimens have not yet undergone the seventh molt.

The mother scorpion died on May 24, 1926. She manifested no symptoms of sickness before dying. It seems reasonable, therefore, to suppose that her life had run its natural course. It is safe to calculate that the life of this species of scorpion, based on the data contained in this paper, may be assumed as being not less than two years and possibly three.

Unfortunately, owing to my departure in the near future for Europe, it will be impossible to continue the study of these scorpions. Up to the present time (February, 1927), the above-mentioned adults have manifested no signs of courtship or other actions which could be interpreted as indicative of an approach to a mating period.

ILLUSTRATIONS

[Photographs taken by W. Schultze and E. Cortes. All figures natural size. * Indicates taken from a living specimen.]

PLATE 1

- FIG. 1. *Palamnaeus longimanus* Herbst (?), female with thirty-four young ones.*
2. Young scorpion one day old.*
 3. Young scorpion about four days old.*
 4. Young scorpion after first molt.*
 5. Exuvia of second molt.
 6. Exuvia of second molt.

PLATE 2

- FIG. 1. Exuvia of third molt.
2. Exuvia of third molt.
 3. Exuvia of third molt.
 4. Exuvia of fourth molt.
 5. Exuvia of fourth molt.
 6. Exuvia of fifth molt.
 7. Young scorpion during sixth instar, shortly before sixth molt.*
 8. Exuvia of sixth molt.

PLATE 3

- FIG. 1. Young scorpion during seventh instar, shortly before seventh molt.*
2. Exuvia of seventh molt.

PLATE 4

- FIG. 1. Old mother scorpion (Plate 1, fig. 1) with the young ones removed.
2. Mother scorpion with thirty-four young ones (lateral view.)*

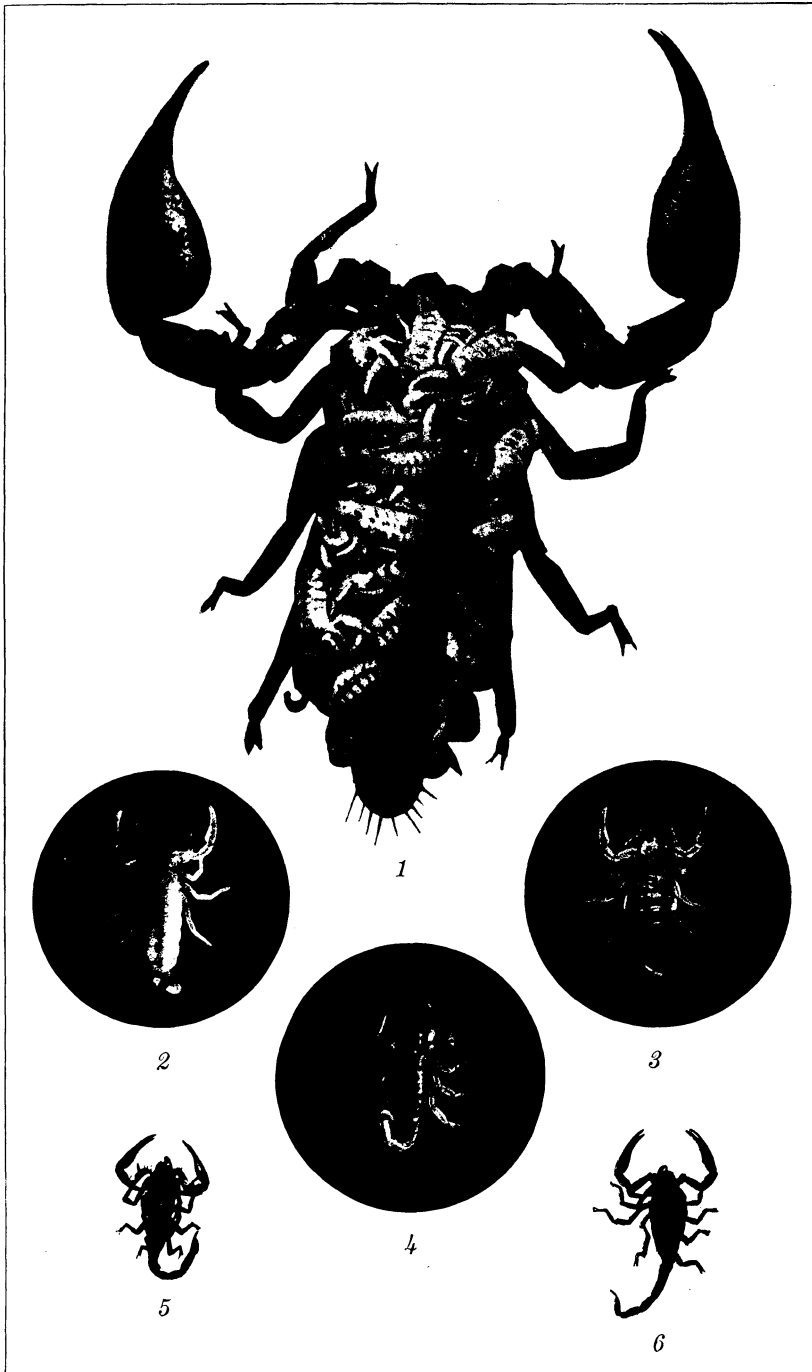


PLATE 1.



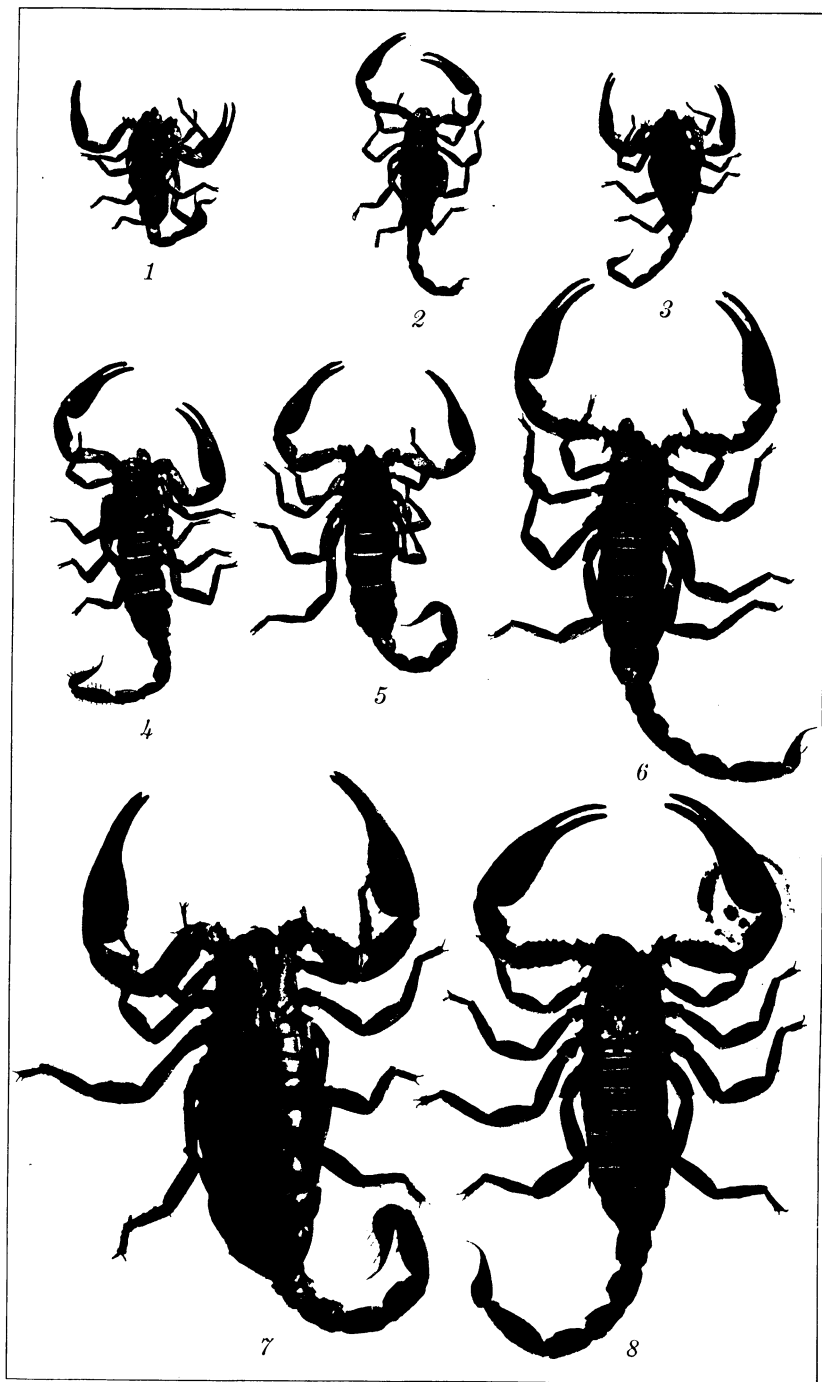


PLATE 2.





PLATE 3



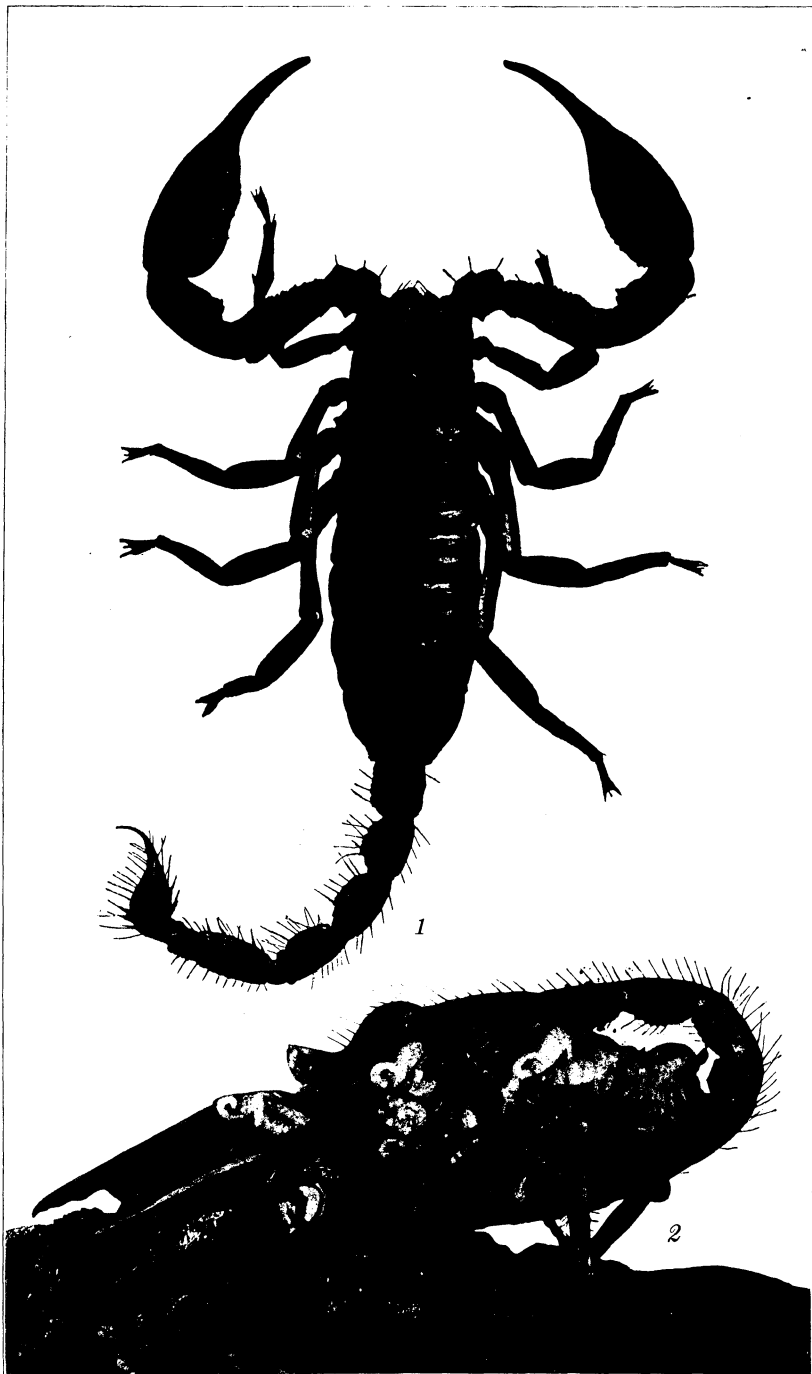


PLATE 4.



SPOLIA MENTAWIENSIA: HOMOPTERA-FULGOROIDEA

By C. F. BAKER

Of Los Baños, Laguna, Philippine Islands

WITH AN INTRODUCTION BY

C. BODEN KLOSS

Director, Raffles Museum, Singapore

ONE PLATE AND TWELVE TEXT FIGURES

INTRODUCTION

By C. BODEN KLOSS

The Mentawi group, to the west of Sumatra, consists of the Islands of Siberut, Sipora, and North and South Pagi. The first and northernmost is larger than the other three (which are fairly equal in size) put together.

Except for the Rhopalocera of Sipora scarcely anything was known of their entomology until I visited Siberut and Sipora during September-November, 1924, accompanied by Mr. N. Smedley, assistant curator of the Raffles Museum, Singapore, and Dr. H. H. Karny, assistant entomologist, Zoölogical Museum, Buitenzorg, Java, with a party of native collectors. I have, as usual, to thank the Government of Netherlands India for the assistance and facilities afforded.

The islands are not very pleasant collecting ground; they are mostly swamp, out of which rise hills nowhere more than 1,500 feet high and generally difficult to get at, being surrounded by soft ground. The sago palm is common. The native villages are situated on the banks of rivers some distance up-stream, and there are scarcely any paths except those made by the Dutch military posts; they are generally through flat land and are often untraversable owing to floods. There is much rain throughout the year. The islands are unhealthy; in spite of systematic employment of quinine and other precautions, all the members of a party of fifteen, except myself, suffered from malaria, either on the islands or soon after leaving them.

The group lies parallel to the west coast of Sumatra and about 60 to 80 miles distant. Siberut is about 70 miles long and about 30 broad, and its northern extremity is on latitude 1° south.

The islands are apparently connected with each other by a sea bottom of less than 100 fathoms, and most bathygraphical charts show a connection with Sumatra, via the Batu Islands to the northeast, by a narrow ridge of similar soundings; but I am inclined to doubt that this ridge is unbroken, as indicated, for the faunas of the groups differ greatly, while, though the Mentawi Islands possess a much richer mammalian fauna than the undoubtedly deep-water islands of Simalur and Engano at the extremities of the western Sumatran chain of islands, the fauna is much more peculiar and differentiated than is that of Nias Island, also represented as being within the 100-fathom line. Whatever the depths may be, they certainly are not those of the shallow Sunda shelf (less than 40 fathoms) on which stand almost all the land masses of Malaysia; that is, the Peninsula, Sumatra, Java, Bali, Borneo, Palawan, etc.

Apart from the connecting ridge the group is surrounded by depths of 100 to 500 fathoms of water; further, everywhere directly between it and Sumatra lies the long Mentawi Basin, with depths of 500 to 1,000 fathoms. Such conditions render several of the western Sumatran islands, in spite of small size and lack of height, zoologically quite as distinct from each other and from the rest of Malaysia as the larger areas of that sub-region are from each other.

The islands are forested all over except for the plantations of the natives, and our material was obtained from various localities near the Government stations of Siberut in the island of that name, and Sioban in Sipora; it came from the seashore, low-lying ground, swamps, cultivated areas, and from such hills as were accessible.

During the journey to and from the islands we also made small collections of insects at Padang, western Sumatra, on Pulau Tello, one of the shallow-water Batu group to the north of Siberut, and on the Pagi Islands, where Doctor Karny also spent several days.

As reports on the various collections obtained are prepared they will be published in various journals under the general title "*Spolia Mentawiensia*."

The following have appeared to date:

Spolia Mentawiensia: Flora. H. N. Ridley, Kew Bulletin of Miscellaneous Information, No. 2 (1926) 56-94.

Spolia Mentawiensia: Birds. F. N. Chasen and C. Boden Kloss, Ibis (April, 1926) 269-305, pl. 3 and fig. 10.

HOMOPTERA-FULGOROIDEA

By C. F. BAKER

FULGORIDÆ S. STR., EURYBRACHIDÆ, LOPHOPIDÆ, DICTYOPHARIDÆ,
FLATIDÆ, RICANIIDÆ, ISSIDÆ, TROPIDUCHIDÆ

The small but interesting series in these fulgorid families is largely composed of more or less widely distributed Malaysian species. Several apparently undescribed species occur in the lot, but none of these can with safety be said to be certainly endemic or peculiar to the Mentawi group, due to the fact that but a very insignificant portion of the homopterous fauna of Sumatra or other Malaysian areas is yet known. No part of the world is richer than Malaysia in Homoptera. Collectors have usually given but little attention to the immense number of species occurring everywhere, either in the Fulgoroidea or the Jassoidea. Even the larger species, commonly of arboreal habit, are far more numerous than was formerly supposed; but, on account of their habits, they are collected with difficulty. It is, therefore, too early to venture any conclusion as to the distribution of these forms, in the case of the archipelago under discussion; that can only come after more comprehensive collections have been made in the various islands and also throughout western Sumatra. The present work, however, will add a number of records to the Mentawi list and also to that of the Batu Islands, a shallow-water group to the north of Siberut, where a small collection was made from which I have described three new species. The present expedition also obtained a few common species in the neighborhood of Padang, west coast of Sumatra, and these records are included herein. The last-named, however, are almost all species of wide distribution which occur also in the Mentawi group as well as in many other areas. While but forty-five species are recorded herein, there undoubtedly exist in the Mentawi Islands at least four hundred species pertaining to these families.

Records without name of collector are to be credited to the Expedition. Specimens collected by Dr. H. H. Karny are credited to him.

NEW SPECIES DESCRIBED IN THIS PAPER

Lophops mentawiensis sp. nov., Siberut, Mentawi Islands.

Trobolophya batuensis sp. nov., Pulau Tello, Batu Islands.

Melicharia karnyi sp. nov., Sumatra and Mentawi Islands.

Seliza siporensis sp. nov., Sipora, Mentawi Islands.

Detya batuensis sp. nov., Pulau Tello, Batu Islands.
Thabenoides smedleyi sp. nov., Pagi, Mentawi Islands.
Paratetrica distanti sp. nov., Pulau Tello, Batu Islands.
Daradax robustus sp. nov., Sipora and Siberut, Mentawi Islands.
Isporisella siporensis g. et sp. nov., Sipora, Mentawi Islands.
Garumna melichari sp. nov., Sipora, Mentawi Islands.

ENUMERATION OF THE SPECIES

FULGORIDÆ s. str.

FULGORA OCULATA Westwood. Plate 1, fig. 1.

This common and variable Malaysian species is represented by one rather deeply colored specimen from Siberut Island.

EUPHRIA DISCOLOR Guérin. Plate 1, fig. 3.

A single specimen of a form of this Sundanese species is labeled "North Pagi Island" (*Karny*).

SCAMANDRA ROSEA Guérin. Plate 1, fig. 4.

A small variety of this widespread Malaysian *Scamandra* is represented by eight specimens from Sipora and Siberut, one of the Sipora specimens bearing the number 227 (*Karny*).

PENTHICODES ATOMARIA Weber. Plate 1, fig. 6.

Two specimens from the adjoining Sumatran coast at Padang. This is a common Malaysian species.

PENTHICODES NIASENSIS Schmidt. Plate 1, fig. 5.

A series of specimens from Sipora and Siberut, and one from North Pagi Island, are referable to this Nias offshoot of *P. scutellata* White, the latter being represented by varying forms in many Malaysian countries.

EURYBRACHIDÆ

THESSITUS INSIGNIS Westwood. Plate 1, figs. 7 and 8.

This characteristic fulgorid of all Malaysian and Philippine regions, which so successfully mimics the bark and lichens of tree trunks, is represented by one specimen from Siberut. It is actually abundant in Malaysian forests, though not often seen unless specially sought, like many others of the larger Fulgoroidea. A small male from Padang is apparently referable to the same species.

LOPHOPIDÆ

APIA LINEOLATA Distant.

A large series shows this species to be abundant in the Mentawi group, specimens coming from Sipora, Siberut, and North Pagi. It was originally described from Singapore, where I have collected it. This species is discussed in a recent paper in

Treubia on the Malaysian representatives of this family, and there figures of it are presented. It will doubtless be found as commonly also in Sumatra, at the right season and on the proper food plant.

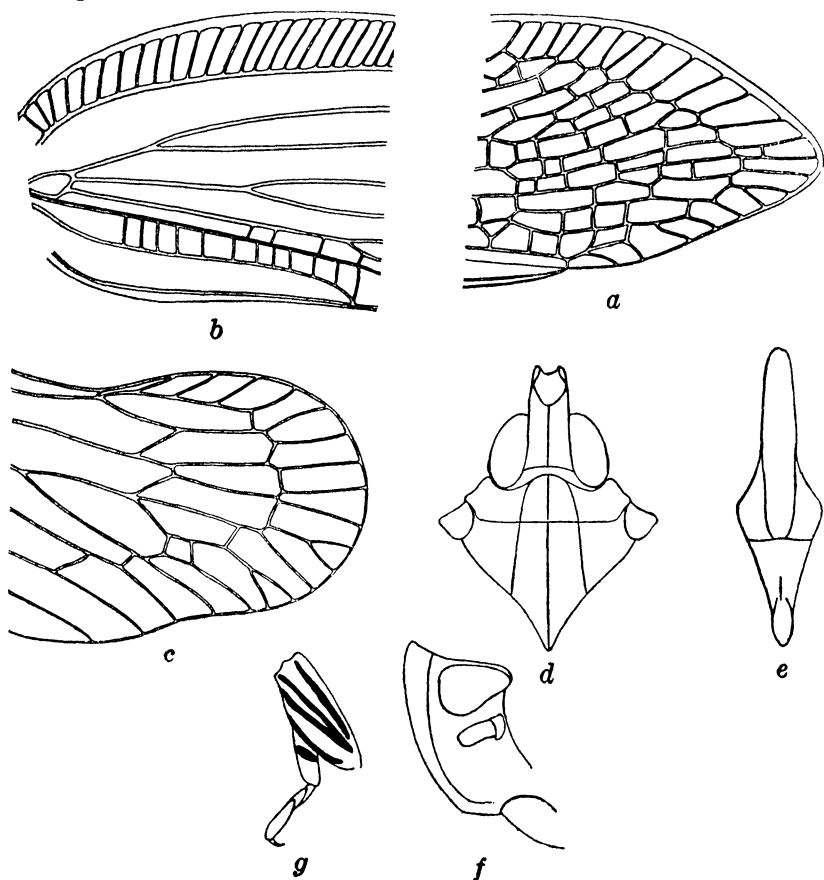


FIG. 1. *Lophops mentawiensis* sp. nov.

LOPHOPS MENTAWIENSIS sp. nov. Plate 1, fig. 14; text fig. 1, a-g.

Length, 10 millimeters; of head, 1 millimeter.

Female.—Testaceous, paler below. A broad smoky stripe passes from near base along subcosta to two-thirds length of tegmen, thence obliquely to apex where it is outwardly bordered with a blackish dash; costal area with about ten narrow oblique stripes which lie at nearly right angles to cross veins; with scattering irregular small darker flecks on corium and clavus. Wings pale smoky throughout. Lateral expansions of front, outwardly with about ten darker cross stripes; a dark line passes

from beneath eye caudad across pro- and mesopleuræ. Fore femora black striped (fig. 1, *g*); fore tibiæ black annulate, some of the spines on remaining legs conspicuously black (fig. 1, *d*, *e*).

In form of head more closely resembling *Lophops carinatus* Kirby but vertex longer in proportion to width (more than twice as long as wide at middle) and distinctly narrowed apically; median carina distinct to frontal border. Side view of face (fig. 1, *f*) very similar to that of *L. carinatus*, the lateral frontal expansions not so wide basally as in *L. zebra*. In frontal view (fig. 1, *e*) the sides of the front are not visible basally, as in *L. zebra* (visible to near extreme base in *L. carinatus*). Tegmina (fig. 1, *a*) somewhat acutely narrowed apically, though more elongately so than in *L. zebra*, and quite distinct in form from *L. carinatus*; with several distinct cross veins in clavus. Venation of wing as shown in fig. 1, *c*.

Described from five specimens from Siberut Island. The type and two cotypes returned to Raffles Museum, two cotypes in Baker collection.

DICTYOPHARIDÆ

MIASA RUBROVITTATA Schmidt.

The typical form of this species, as described by Schmidt from Java and Sumatra, appears to be common in the Mentawi group, specimens coming from Sipora, Siberut, and North Pagi. The genus is one of several in this family that are highly characteristic of Malaysia.

CENTROMERIA SPEILINEA Walker.

A common and widely distributed Malaysian species to be expected everywhere. Specimens come from Sipora, Siberut, and North Pagi Island.

TROPIDOPHORA JAVANA Lethierry.

This specimen is common throughout Java and Sumatra. Five specimens come from Siberut Island.

TROBOLOPHYA BATUENSIS sp. nov. Text fig. 2, a-e.

Length, female, 5.75 millimeters; male, 5.

Color pale testaceous (doubtless pale green in life), tegmina and wings hyaline, veins fuscous. Side of head above eye with a small indistinct dark mark or unicolorous. Vertex apically with two small black longitudinal dashes.

Apparently very close to *T. jacobsoni* Melichar,¹ but not agreeing with either description or figures of that species as figured by Melichar (f. 2).

Lateral margins of vertex (fig. 2, *c*) concave, leaving sides of front broadly visible in dorsal view, length of intraocular portion equaling that of anteocular. In side view (fig. 2, *e*) the angle between vertex and front is slightly less than a right angle. Sides of front (fig. 2, *d*) outcurved on basal half, broadest considerably before clypeus; venation of tegmina and wings as shown in fig. 2 *a*, *b*.

Described from six specimens from Pulau Tello, Batu Islands (*Karny*) and numbered 253, 254, 255. The type and three cotypes have been returned to Raffles Museum; two cotypes in Baker collection.

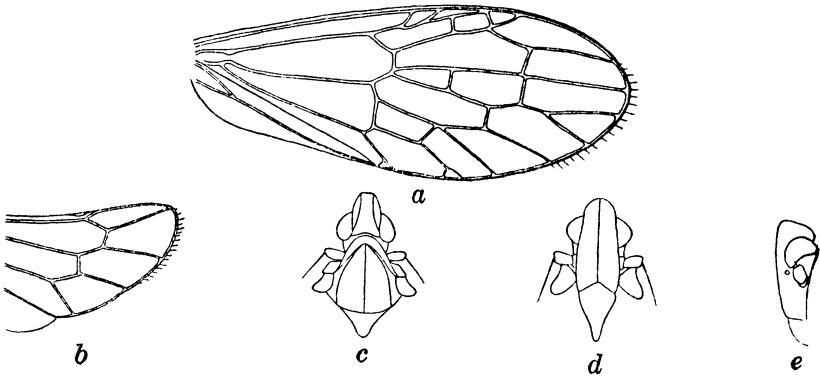


FIG. 2. *Trobolophya batuensis* sp. nov.

As remarked in the discussion of the species of this genus,² the details of structure in *T. jacobsoni* must be reviewed, and more material from the type locality (Nongkodijadjar, Java) is greatly needed. From what has been presented, however, it seems that *T. batuensis* is an entirely distinct species.

The genus *Trobolophya* has been redescribed from southern India by Distant³ under the name *Stacotoides* and there placed in the family Tropicoduchidae. His species *typicus* appears to be quite distinct from *batuensis*. Distant's figures are apparently incorrect in several important respects; the cross vein at base

¹ Notes Leyden Mus. 36 (1913) 94, f. 1.

² Philip. Journ. Sci. 15 (1919) 303.

³ Fauna Brit. Ind. Rhynch. 6 (1916) 50.

of inner apical cell appears to be omitted; the form of front should be reëxamined.

In the same year (1913) that Melichar described *Trobolophya*, but later in the year, Muir apparently described the same genus under the name *Neommatissus* ⁴ from Amboina, placing it in the Cixiidæ.

DICTYOPHARA PALLIDA Don.

Probably the commonest member of this family in the Far East. Widely distributed and variable. Specimens come from Siberut.

FLATIDÆ

LAWANA OPTATA Melichar forma. Plate 1, fig. 2.

One specimen from Padang. Distributed widely through Malaysia. I have specimens from Singapore and Penang. The species of this genus are highly variable and should be collected in large series in all regions.

NEPHESA COROMANDELIANA Spinola.

Two specimens come from Siberut and one from Sipora. Widely distributed.

NEPHESA ROSEA Spinola.

One specimen from Padang. Also widely distributed and highly variable.

MELICHARIA KARNYI sp. nov. Text fig. 3, c, e.

Length, female, 11.5 millimeters; male, 10.5.

Several specimens in the material sent me were labeled "*Melicharia quadrata*," by Doctor Karny, and apparently in conformity with his recent report of this species in southern Sumatra.⁵ Fortunately, I have specimens of true *quadrata* from Ceylon, and comparison shows that this species (*karnyi*) is more nearly related to *M. (Anaya) fuscomarginata* than to *quadrata*. *Melicharia fuscomarginata* is an abundant Malaysian species, marked by a very broad, short face, like *quadrata*; *quadrata*, however, has a sharply right-angled sutural angle, while in both *fuscomarginata* and *karnyi* this angle is distinctly more than a right angle and obtusely rounded. The crown of head visible from above in *karnyi* (fig. 3, e) is much longer in proportion to width, and much farther extended in front of eyes than in either *quadrata* (fig. 3, d) or *fuscomarginata*, and the front is much longer in proportion to width (fig. 3, a, *quadrata*; b, *fuscomar-*

⁴ Proc. Haw. Ent. Soc. 2 (1913) 267.

⁵ Treubia 3 (1922) 4.

ginata; *c*, *karnyi*). In coloration *karnyi* resembles *fuscmarginata* more nearly than it does *quadrata*, being pale greenish (fading to ochraceous), the sutural and apical borders of tegmina very narrowly smoky.

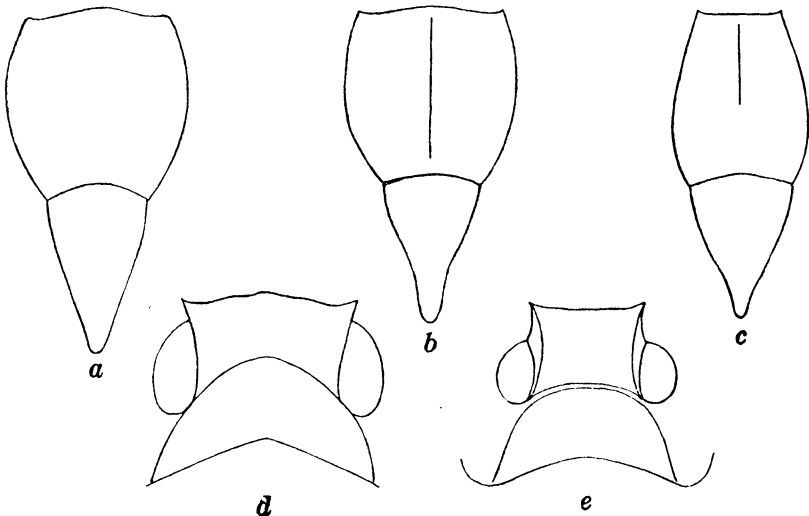


FIG. 3. *a*, *d*, *Melicharia quadrata* Kirby; *b*, *Melicharia fuscmarginata* Melichar; *c*, *e*, *Melicharia karnyi* sp. nov.

Described from four specimens, the type from Padang, with a cotype from Sipora (*Karny*), these returned to Raffles Museum. Two cotypes, one from Padang and the other from Siberut (*Karny*) in Baker collection.

This species appears to bear no relationship to species recently described by Schmidt or Jacobi.

MELICHARIA NIVEINA Walker.

Specimens come from Sipora (*Karny*), from South Pagi (*Karny*), and from Siberut. Widely distributed and common throughout Malaysia.

MELICHARIA FUSCOMARGINATA Melichar. Text fig. 3, b.

A large series of this common Malaysian species contains specimens from all of the islands visited, except Sumatra. Some of these specimens bore the label "*Anaya* n. sp.," though the species appears to be typical *fuscmarginata*. Distant and Melichar have placed the questionable genus *Anaya* in the *Seliziinæ*, though it is a close relative of the other "*Ormenis*" segregates and its real relationship seems to be with *Melicharia*, to which this species was formerly referred. It may be left in *Melicharia* until the question as to *Anaya* can be cleared up.

SELIZA SIPORENSIS sp. nov. Text fig. 4, a, b.

Length, 8 millimeters, width of tegmen, 4; width of head, 1.

Pale brown; tegmen with costal area and clavus somewhat darkened, and with a discal clouding opposite apex of costal area; a small round dark spot on corium opposite middle of claval suture; wings smoky, centrally paler.

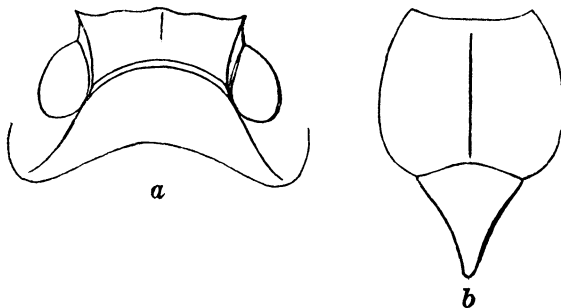


FIG. 4. *Seliza siporensis* sp. nov.

Crown of head (fig. 4, *a*) shorter than pronotum, its width at apex more than three times length at middle, anterior margin sinuate-truncate. Front (fig. 4, *b*) with sides strongly out-curved, its median length three-fourths of width at middle (fig. 4, *b*), a low, broad, rather indistinct facial carina continuous throughout from disk of clypeus to base of vertex. Tegmen very broad, breadth at middle more than half of length, squarely truncate apically, with the angles broadly rounded, the sinuations of margins distad of apices of costal area and clavus very shallow; costal margin not very strongly outcurved; granulations of clavus confined to basal and middle areas.

Described from one specimen from Sipora; returned to Raffles Museum.

ATRACIS LURIDA Melichar.

A single specimen of this Sundanese species comes from Siberut.

RICANIIDÆ

POCHAZIA MARGINATA Walker.

One specimen from Sipora. Throughout Malaysia.

POCHAZIA FUSCATA Fabricius.

Two specimens from Siberut, one from Sipora. Throughout Malaysia.

POCHAZIA SINUATA Stål.

Four specimens from Siberut. Another specimen from Siberut has the tegminal bands yellowish instead of the typical white, and belongs to the form *ochracea* Schmidt. Throughout Malaysia.

RICANIA MARGINALIS Walker.

One specimen from Padang. Throughout Malaysia.

RICANIA SIGNATA Stål.

Four specimens from Pulau Tello, Batu Islands, one from Sipora, and two from Siberut. Originally described from the Philippines, but afterward found to be generally distributed through Malaysia.

RICANIA DISCOPTERA Stål.

Four specimens from Siberut. A common Sundanese species.

RICANIA STUPIDA Walker forma. Plate 1, fig. 10.

One specimen from Siberut represents a form of this widely distributed and variable Malaysian species. The apical spot of tegmen is here smaller and less conspicuous.

RICANOPTERA MELLERBORGI Stål.

A large series of this very abundant Malaysian species contains many specimens from all of the islands visited.

DETYA FUSCONEBULOSA Distant. Plate 1, fig. 9.

A series of specimens of this well-marked species comes from Siberut. Of general distribution through southeastern Asia and Malaysia.

DETYA BATUENSIS sp. nov. Plate 1, fig. 12; text fig. 5, a-g.

A much smaller species than either *D. fusconebulosa* Distant or *D. sublineata* Walker, and with almost entirely unmarked, hyaline tegmina.

Length, 11 millimeters; length of tegmen, 10; width at middle, 5.

Pale ochraceous; facial carinæ fuscous but without dark granulations; small black spots on sides of head above eyes, on propleuræ, and on mesopleuræ; hind borders of abdominal segments infuscated; vertex with two lateral oblique black spots and mesonotum with four on either side (fig. 5, e). Tegmina hyaline, except for a few indistinct small smoky spots on subcostal and subapical cells, a small fuscous callous thickening

beyond end of subcostal cell and a similar, still smaller one in basal portion of cubital cell; veins fuscous, some at apex of costal area and about half of those on disk paler. Wings with an indistinctly smoky apical border.

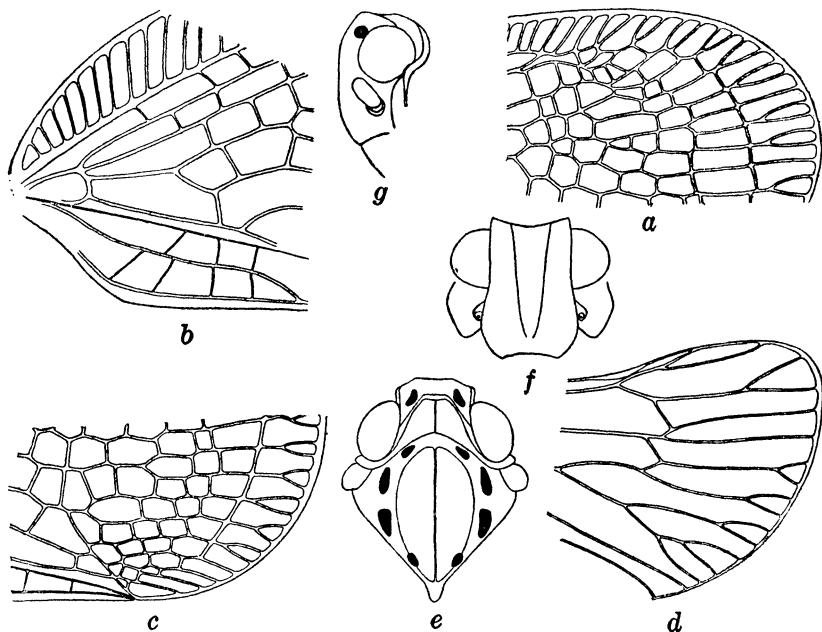


FIG. 5. *Detya batuensis* sp. nov.

Front (fig. 5, *f*) proportionally broader than in *D. fusconebulosa* Distant, the greatest width above clypeus nearly three-fourths of length. Proportions of head and thorax above, and head in lateral view are shown in fig. 5, *e*, *g*. Tegmina with cells before subapical series more numerous and much more regular (fig. 5, *a*, *c*) and the cross veins toward base more numerous (fig. 5, *b*); wings with but one fork in first apical vein (fig. 5, *d*).

Described from two specimens taken on Pulau Tello, Batu Islands. The type returned to Raffles Museum, one cotype in Baker collection.

GONIOPSIS MYSTICA Melichar. Plate 1, fig. 11.

A single specimen of this rather uncommon species is labeled "Pagi Ids.-Karny." The species was described from Singapore, where it was also taken by me.

ISSIDÆ

HEMISPHAERIUS IMITATUS Melichar.

A specimen each from Sipora, Siberut, and Pulau Tello, Batu Islands. Described from Sumatra.

GERGITHUS SIGNATIFRONS Melichar.

One specimen from Siberut. This is a male, 5 millimeters in length (Melichar gives 5.5 millimeters for both sexes). Melichar's specimens were evidently not fresh, since the lateral areas of front to either side of the blood red median area described by him as "blassgelblich" are, in life, pale bluish green and the apical connection is yellowish; the front apically and the clypeus medially are also red; there is a small blue-green spot on the propleura, a blackish spot on mesopleuræ, and the metapleuræ are reddish. In old or alcoholic specimens these colors might largely disappear. In other respects this specimen fits closely the description of Melichar.

GELASTYRA LATIFRONS Melichar. Plate 1, fig. 19; text fig. 6, a-e.

Two specimens, labeled "Pagi Ids.-Karny." This clearly marked species was described by Melichar from Sumatra, but also recorded from Burma, and from the misspelled locality "Mentawei, Sipopa." The latter undoubtedly refers to Sipora.

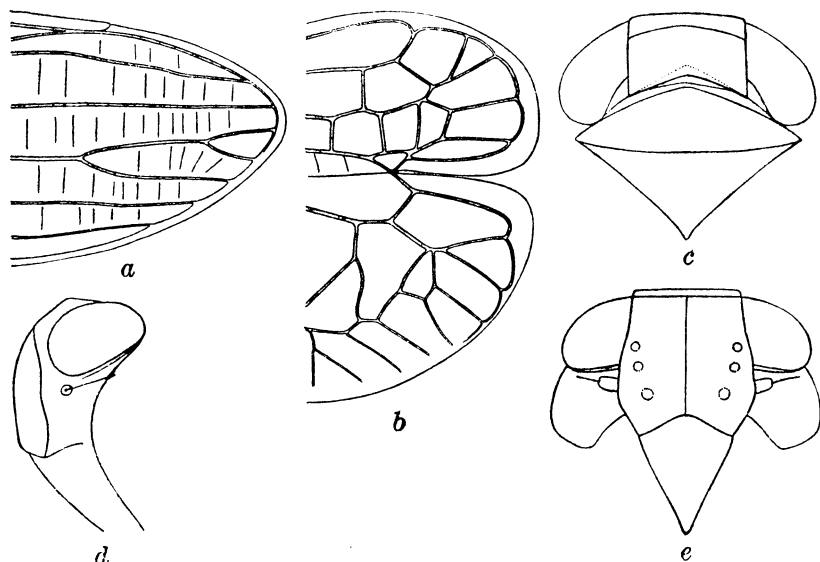


FIG. 6. *Gelastyra latifrons* Melichar.

In as much as no illustrations have been presented for this species, its important structural details are outlined in fig. 6, *a-e*. It is of the highest importance in the Issidæ to illustrate the venation of tegmina and wings carefully, since these furnish important classificatory characters.

THABENOIDES SMEDLEYI sp. nov. Text fig. 7, *a-e*.

Very similar to the chocolate brown *T. albinotatus* Distant, but without any of the paler markings described for that South Indian species.

Length, 6 millimeters.

Vertex (fig. 7, *c*) longer and narrower than in *T. albinotatus* and more extended and broadened before eyes, but of the same general form as in *T. albinotatus*. Pronotum acute apically. Front (fig. 7, *d*) longer, narrower basally, and basal margins more incurved, the lateral margins more strongly outcurved above clypeus. Cross veins of corium very indistinct; costal area (fig. 7, *a*) broader than subcostal. Wing (fig. 7, *b*) with very simple venation, but the two approximate veins immediately before lobar fold parallel, joined by a strong terminal loop and with several cross veins between them.

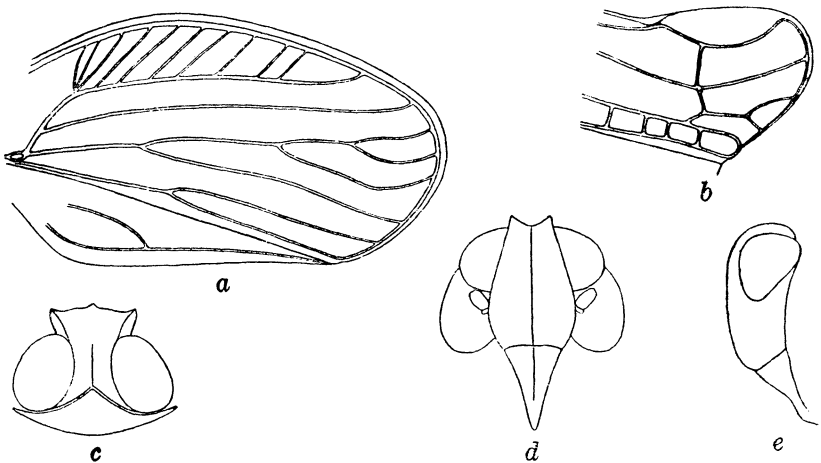


FIG. 7. *Thabenoides smedleyi* sp. nov.

Described from one specimen labeled "Pagi Ids.-Karny." Type returned to Raffles Museum. This species goes into *Thabenoides* better than into any other genus, though differing in several details, as described above. It apparently differs from *Thabenoides* most widely in wing venation, according to a sketch kindly sent to me by Mr. China of the

British Museum; but in as much as it so closely corresponds in other characters, it is for the present placed in this genus.

SARIMA sp.

One specimen in poor condition from Sipora (*Karny*). More material is necessary before proper determination can be made.

PARATETRICA DISTANTI sp. nov. Text fig. 8, a-e.

One specimen from Pulau Tello, Batu Islands, has the two fissural veins (fig. 8, b) coalesced apically and the front somewhat longer than broad, and these with its other characters place it in *Paratetricea*. There is a very faint indication of a median keel on vertex, though in certain lights this appears to be absent.

Length, 6 millimeters.

Pale brown. Front with two large pale spots adjoining middle of median carina and numerous small pale spots on either side adjoining lateral carinæ. Apical third of tegmina and extreme base paler, a broad albescent oblique band crossing corium at middle, and clavus apically. Wings slightly uniformly smoky.

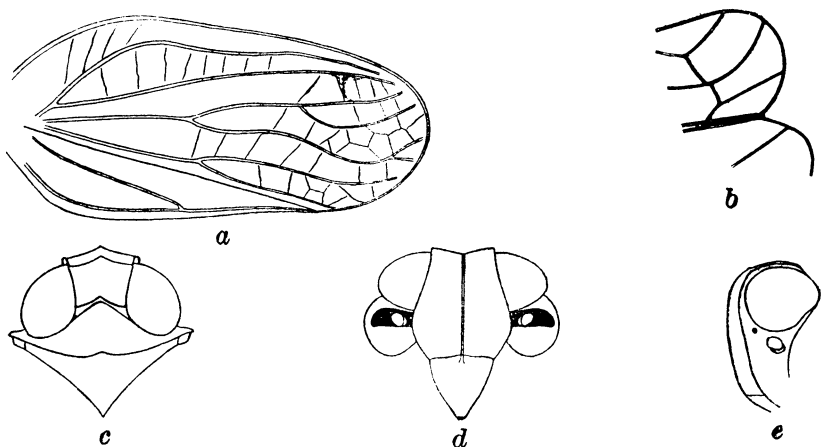


FIG. 8. *Paratetricea distanti* sp. nov.

Vertex (fig. 8, c) broader than long and somewhat acute angulate anteriorly. Front (fig. 8, d) a little longer than broad, rather suddenly broadened below eyes and angulately emarginate basally, with a strong median carina. The strongly declinate clypeus is heavily carinate basally. The antennæ appear very pale against a blackish irregular mark on propleuræ (over-emphasized in figure). The curve of head in lateral view (fig. 8, e) is quite even from base to apex, most prominent at

frontoclypeal suture. Cross veins in corium very weak and becoming more or less reticulate apically.

TEMPSA MALAYA Stål. Plate 1, fig. 18.

This common Malaysian species is represented by one specimen from Sipora and one from Siberut (*Karney*).

GLYPHOTONGA ACUMINATA Schmidt. Plate 1, fig. 17; text fig. 10, a-e.

One specimen of this remarkable species, described from Sumatra and Perak, Malay Peninsula,⁶ was taken in Siberut (*Karney*). Since it has not been figured, some of its structural details are given here (fig. 10, a-e). The form of head (fig. 10, c-e) and of tegmina (fig. 10, a, b) are most distinctive.

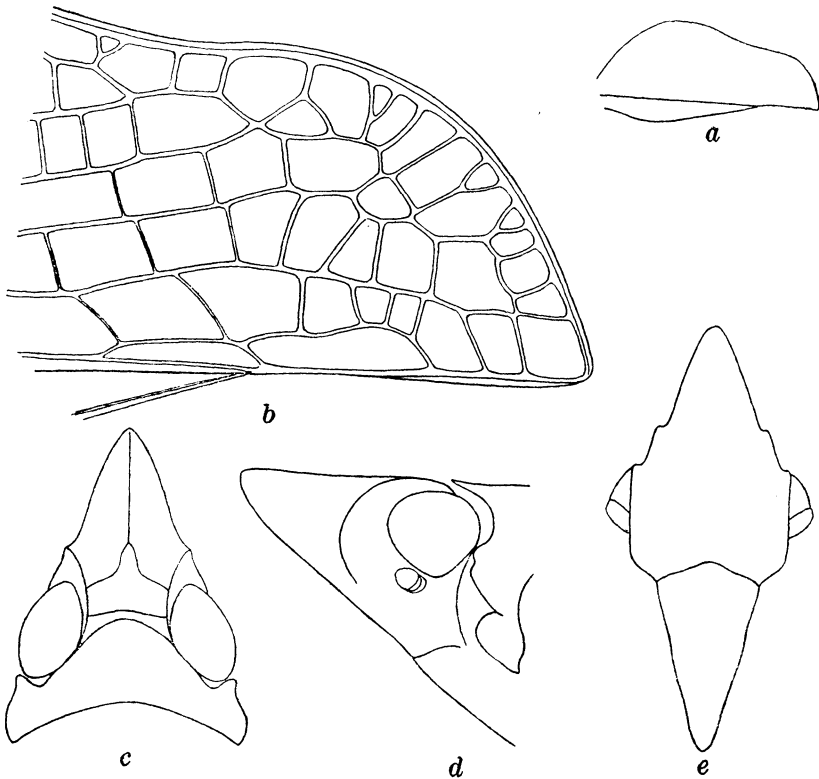


FIG. 10. *Glyphotonga acuminata* Schmidt.

This genus was redescribed under the name *Oxychara* by Melichar⁷ and, strangely enough, placed in the American family Acanaloniidae. Mr. China now calls my attention to the fact that it was also redescribed by Distant in 1914 under the name

⁶ Stett. Ent. Zeit. 71 (1910) 187.

⁷ Wyts. Gen. Ins. fasc. 182 (1923).

Neodelia. China also remarks (in litt.) that *Neodelia moultoni* Distant is *Glyphotonga cyardiformis* Melichar. The relationship of the genus appears to be with *Tonga*, and to the Tonginæ; apparently here should be referred also *Forculus* Distant, *Forculusoides* Distant, *Orthophana* Melichar, *Paratonga* Schmidt, *Oryxana* Distant, and *Hemitonga* Schmidt. They all have one or two subapical teeth on hind tibiæ, but this character is variable. In more stable characters they appear to be Issidæ.

TROPIDUCHIDÆ

DARADAX ROBUSTUS sp. nov. Plate 1, fig. 13; text fig. 11, a-f.

Length, male and female, 13 to 14 millimeters.

Pale green (to ochraceous in dried specimens), paler below; sides of front darkened, temples and vertex minutely mottled;

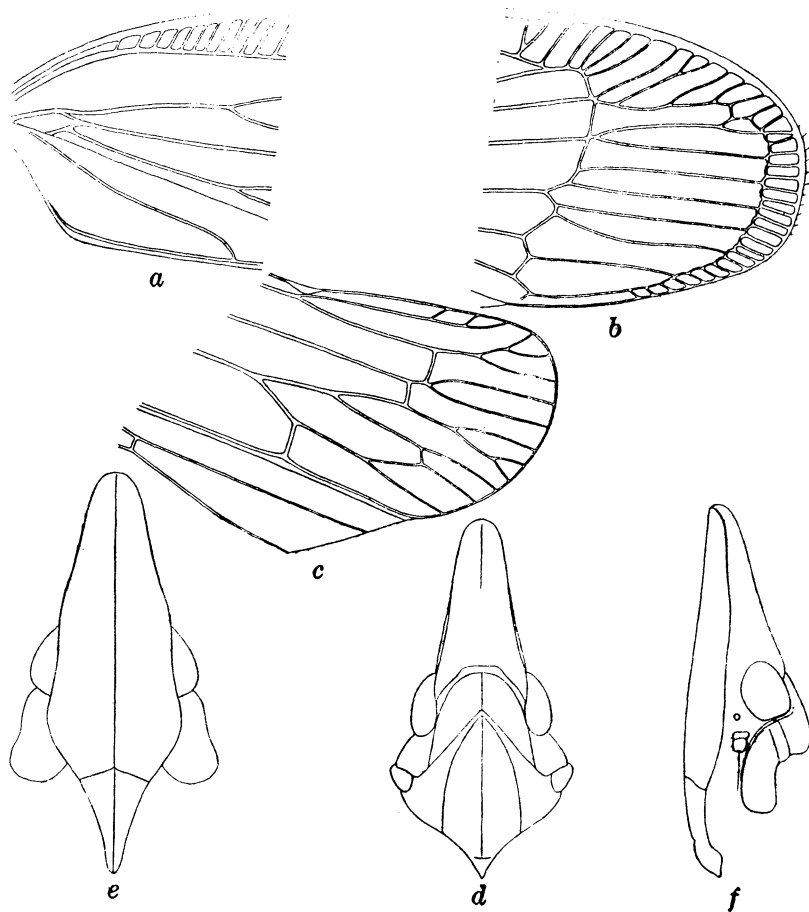


FIG. 11. *Daradax robustus* sp. nov.

a dark spot at tip of clavus and with fuscous mottlings in the apical area; corium otherwise clear unicolorous pale green.

Length of vertex one and a half times width between eyes, the narrowed apex (fig. 11, *d*) bluntly rounded; median carina more distinct on apical half. Front more than twice as long as broad below eyes (fig. 11, *d*), and with a strong median carina which continues on to clypeus, where it is somewhat angulate apically. Pronotum coarsely irregularly granulate, pitted, and with two approximate sharp longitudinal lateral carinae behind eye. Tegmina and wings with venation as in fig. 11, *a-c*.

Described from one specimen from Sipora, two from Siberut (*Karny*), and two from Siberut collected by the Expedition. The type and two cotypes have been returned to the Raffles Museum; two cotypes in Baker collection. I also have specimens of the same species from Singapore and North Borneo. It appears to be abundant throughout Malaysia. It seems almost incredible that this species should not have been described before, but it is not *D. nasutus* Melichar, its only near relative in Melichar's monograph.

VARMA FERVENS Walker. Plate 1, fig. 15.

The collection contains a number of specimens of this common and variable Malaysian species from Siberut, Sipora, and Pulau Tello, Batu Islands.

EPORA SUBTILIS Walker.

This widely distributed Indo-Malaysian species is represented by several specimens from Siberut and Padang. It may be expected everywhere in Malaysia.

Genus **ISPORISELLA** novum

Nearest to *Isporisa* Walker, from which it differs as follows: Position of median carina of front marked only by a brown line on apical half but this resting on a broad median longitudinal raised portion of the surface which is nearly parallel-sided. The clypeus neither as long nor as wide as front, with a strongly raised median keel which apically is strongly angulate (in side view, fig. 12, *e*), the tip of clypeus thus delimited. Venation of wing and tegmen as shown in fig. 12, *a, b*.

Type, *Isporisella siporensis* sp. nov.

ISPORISELLA SIPORENSIS sp. nov. Plate 1, fig. 16; text fig. 12, *a-e*.

Length, 8 millimeters, female and male.

Sordid ochraceous, paler beneath. Pits of vertex and pronotum blackened, and two small black spots on mesonotum out-

side of lateral carinæ. Base of front with entire rondeur on to crown at apex of vertex, smoothly evenly swollen, shining black, and with a median crescentic yellow mark. Front below with two quadrangular red marks on either side. Clypeus dark at base. A horizontal black stripe across mesopleuræ and a black spot on metapleuræ. Femora with indistinct apical annulæ, and lateral stripes. Tibial spurs unicolorous. Tegmina faintly, evenly suffused with ochraceous, the wings hyaline, in some cases with a small dark spot on disk of corium before middle and another in clavus.

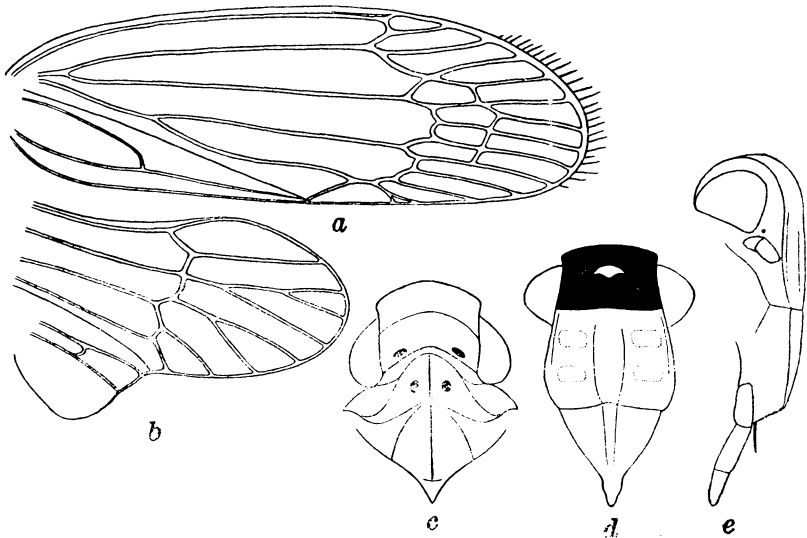


FIG. 12. *Isporisella siporensis* sp. nov.

Vertex deeply concave, its anterior margin high to meet the rondeur of the front, its length but little more than that of the moiety of the front seen from above (fig. 12, c), its width about three times the length. Front about a fifth longer than wide, the sides below eyes strongly outcurved.

Described from five specimens from Sipora. The type and two cotypes have been returned to the Raffles Museum; two cotypes in Baker collection.

GARUMNA MELICHARI sp. nov. Text fig. 13, a-e.

Length, 5.75 millimeters.

Very close to the Celebesian *G. lepida* Melichar, but larger. Coloration nearly the same, but the entire head above the lateral carinæ of front very smooth and shining, deep black (except

narrow lateral portions of anterior margin of vertex) ; a large part of the apical plane portion of front (except at basal reëntering angles, fig. 13, *d*) dark brown. Pronotum shining black anteriorly.

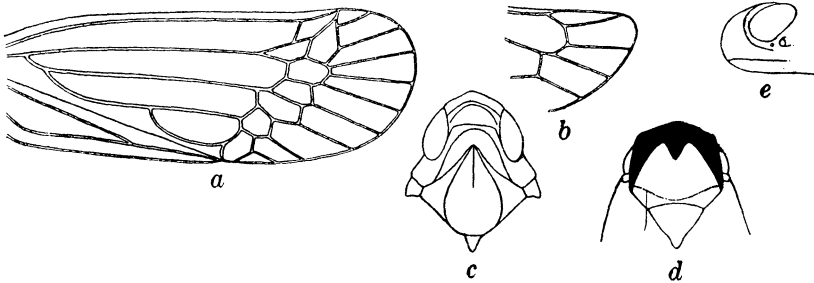


FIG. 13. *Garimna melichari* sp. nov.

The head is strongly flattened above and below, the lower part of face being nearly horizontal. The vertex stands in same plane as the base of front (fig. 13, *c*, *e*). Venation of tegmen and wing as in fig. 13, *a*, *b*. From Sipora Island; one example only.

Melichar described but one species of this genus; but there are several distinct species in Malaysia and the Philippines. All that I have seen have the entire rondeur of head and the vertex pale yellowish, with at most a narrow black band across plane portion of front. In all of the species the markings of tegmina are closely similar to those described for *lepida*. Type returned to the Raffles Museum.

ILLUSTRATIONS

[Photographs for plate, as well as reduced photographs of drawings for text figures, by
Bureau of Science, Manila.]

PLATE 1

- FIG. 1. *Fulgora oculata* Westwood, forma.
2. *Lawana optata* Melichar, forma.
3. *Euphria discolor* Guérin, var.
4. *Scamandra rosea* Guérin, var.
5. *Penthicodes niasensis* Schmidt.
6. *Penthicodes atomaria* Weber.
7. *Thessitus insignis* Westwood, female.
8. *Thessitus insignis* Westwood, male, forma.
9. *Detya fusconebulosa* Distant.
10. *Ricania stupida* Walker, forma.
11. *Goniopsis mystica* Melichar.
12. *Detya batuensis* sp. nov.
13. *Daradax robustus* sp. nov.
14. *Lophops mentawiensis* sp. nov.
15. *Varma fervens* Walker.
16. *Isporisella siporensis* sp. nov.
17. *Glyphotonga acuminata* Schmidt.
18. *Tempsa malaya* Stål.
19. *Gelastyra latifrons* Melichar.

TEXT FIGURES

- FIG. 1. *Lophops mentawiensis* sp. nov.
2. *Trobolophya batuensis* sp. nov.
3. Three species of *Melicharia*; a, d, *Melicharia quadrata* Kirby; b, *Melicharia fuscomarginata* Melichar; c, e, *Melicharia karnyi* sp. nov.
4. *Seliza siporensis* sp. nov.
5. *Detya batuensis* sp. nov.
6. *Gelastyra latifrons* Melichar.
7. *Thabenoides smedleyi* sp. nov.
8. *Paratetrica distantii* sp. nov.
9. Omitted.
10. *Glyphotonga acuminata* Schmidt.
11. *Daradax robustus* sp. nov.
12. *Isporisella siporensis* sp. nov.
13. *Garumna melichari* sp. nov.

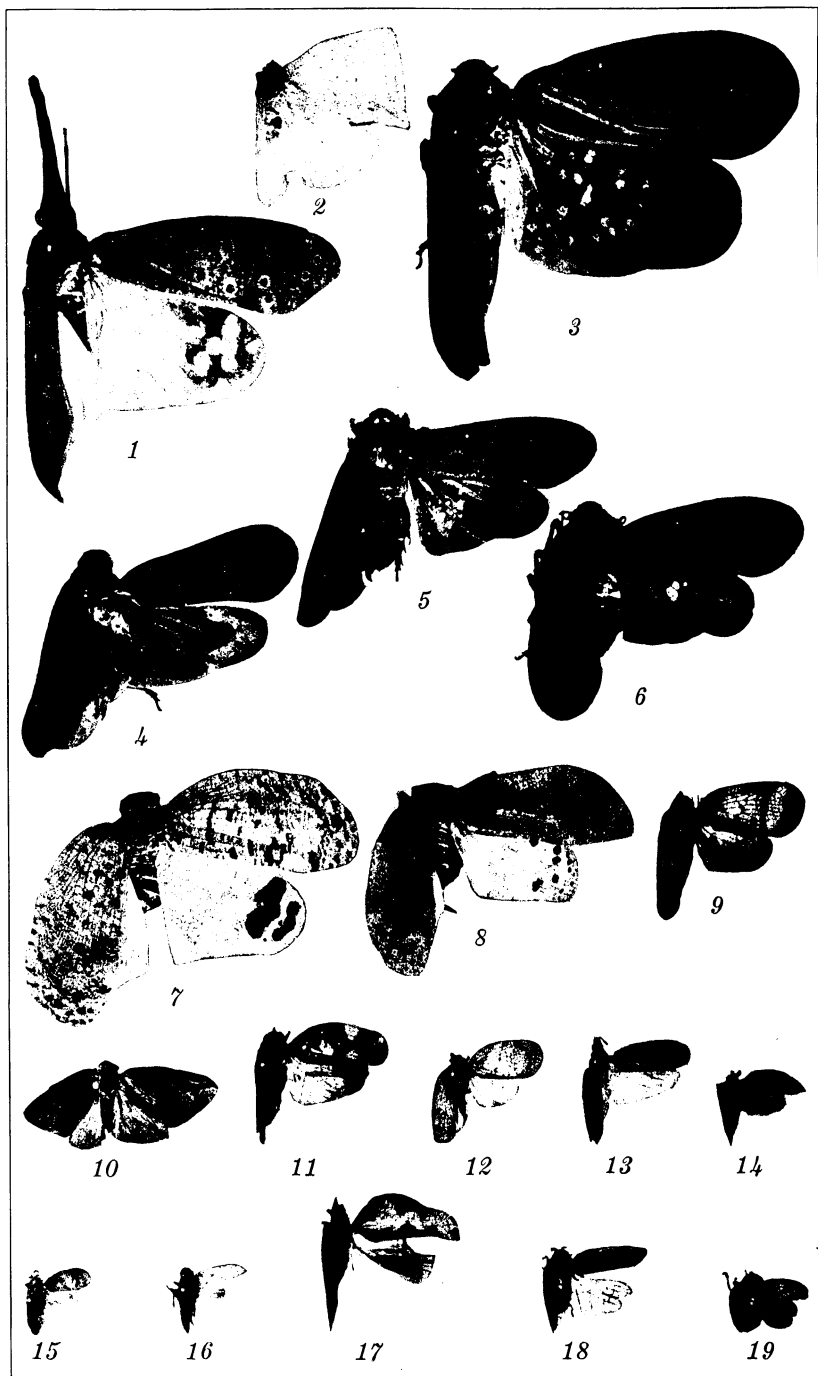


PLATE 1.

A NEW GENUS AND THREE NEW SPECIES OF PHILIPPINE FISHES

By ALBERT W. HERRE

Chief, Division of Fisheries, Bureau of Science, Manila

TWO PLATES

Genus MIROLABRICHTHYS novum

This genus can be distinguished at a glance by the remarkable proboscislike, fleshy, pointed tip on the premaxillary, and the scalation of the head.

The body appears elongate but is really deep, somewhat ellipsoid, everywhere covered with medium-sized ctenoid scales, those on the head much smaller and extending to tip of snout; very small scales cover the preorbital, maxillary, cheeks, opercles, and throat; the dorsal and anal are scaled basally and tiny scales extend upon their free portion; caudal covered with minute scales for half or three-fourths its length; the ventral is elongate, pointed, and one or two of the rays may be very elongate and filiform; mouth of moderate size, the maxillary not slipping under a sheath except anteriorly; upper jaw, or premaxillary, has a narrow band of fine teeth on each side posteriorly, becoming a large patch at anterior end of premaxillary and terminating in a stout canine; the lower jaw has very small teeth in narrow bands posteriorly, with a pair of canines at anterior tip, and one or two pairs of enlarged teeth a little way behind them; branchiostegals 6; pseudobranchiæ present. This genus is close to *Caesio* but is markedly differentiated from it.

Mirus, wonderful; *labrum*, lip; *ἰκθῆς*, fish.

MIROLABRICHTHYS TUKA Herre and Montalban sp. nov. Plate 1.

Dorsal IX to XI, 14 to 16; anal III, 7; there are 45 to 48 scales in the lateral line, 5 between the origin of the dorsal and the lateral line, 12 between the lateral line and the origin of the anal.

The somewhat ellipsoid, rather deep body is scaled as given for the genus; dorsal and ventral profiles almost equally convex,

the depth 2.8 to 2.93 times in the length; the small pointed head is slightly concave on snout and is remarkable for the elongate, conical, pointed, fleshy tip projecting from the premaxillary, its length 3.11 to 3.4 times in the total length; the tip on snout contained about 2.5 times in the circular eye which is 4.5 times in the head, 1.4 to 1.66 times in the snout, and $1\frac{1}{8}$ to $1\frac{1}{8}$ times in the rather broad interorbital; posterior margin of eye more or less denticulate; mouth of medium size, oblique, the posterior margin of maxillary extending beyond eye, the greatest width of maxillary two-thirds that of eye, the lower jaw included, its tip coming to the base of the fleshy snout tip, and most of its length concealed by the broad maxillary; the teeth as given for the genus; the posterior margin of preopercle finely denticulate; the opercle has two flat spines on its posterior margin, the upper one larger and extending farther backward, with an elongated epidermal flap beneath them and extending still farther back; the first dorsal spine short, the others successively longer to the fourth, the rest subequal, about 4 times in the depth; the normal number of spines seems to be ten; the soft dorsal elevated, the posterior margin sharply angulate, the posterior portion elongate, the last four rays successively shortened, the fifth from the last equal or nearly equal to head, extending upon caudal when depressed; the second anal spine is the stoutest, the third the longest; the third or fourth anal ray is longest, shorter than the longest dorsal rays, not reaching base of caudal when depressed, the posterior margin of anal acutely angulate; depth of caudal peduncle almost equals its length, and is contained a trifle more than twice in head; caudal deeply lobate, the longest ray in both upper and lower lobes more or less filiform, equal to or greater than the depth; the pectoral elongate, about $1\frac{1}{8}$ times in the head; the ventrals elongate, pointed, the second and third rays often very elongate and threadlike, when they extend upon the anal and are more than the head or the depth.

Color in alcohol dusky reddish brown above, becoming paler and yellowish with reddish glints below, the fins all pale whitish yellow, without marks; a faint reddish or pinkish band extends from behind eye to base of caudal and another one from beneath pectoral backward along side to lower end of caudal base; a blackish blotch on opercle; a violet brown patch on basal portion of posterior two-thirds of soft dorsal. When fresh the color was brownish red above, the sides roseate, with two longitudinal

golden red bands, the fins golden, the patch on the soft dorsal violet.

Here described from the type and three cotypes, 84 to 94 millimeters in length, collected at Maricaban Island, in a school of *Caesio*.

Tuka, Tagalog for beak, in allusion to the projecting tip on the snout.

STEPHANOLEPIS NIGROLINEATUS Herre sp. nov.

Dorsal I-I, 29; anal 25.

The depth from the soft dorsal to origin of anal is 2 to 2.18 times in the length; body roughly oblong with pointed head, both much compressed laterally; head 3.2 to 3.27 times in the length; snout elongate with very convex dorsal profile, 1.5 times in head; the circular eye high up, about two-thirds its diameter below the upper profile of the convex interorbital space, 3 times in head and twice in snout; the lower extremity of the diagonal gill slit is just in front of the upper part of pectoral base; it is inclined at an angle of about 45° , its upper extremity beneath posterior margin of eye, its length twice in eye; the stout, backward-curved dorsal spine is over middle of eye, its length equal to that of snout; anterior surface of spine very rough with many small, upward-directed, pointed spinelets; on each corner of the posterior surface is a row of seven to nine stout barbs pointing downward and outward; the short, freely movable ventral spine has a terminal spine and two lateral spines on each side; first dorsal ray low, the next three elongated or very elongate and filiform, in one specimen about as long as head, the other rays uniform, low, equal to anal rays in height, less than an eye diameter in height; the anal rays all about the same height; the length of the subtruncate caudal equals snout, one and a half times in head, or twice eye.

Body covered with very small scales, each bearing on its posterior margin a slender spinelet or prickle; anteriorly these are very short and fine, but on the posterior half of body they become elongate and on caudal peduncle are stouter, recurved, forming a mat of conspicuous bristles.

Color in alcohol blackish gray, a little paler on throat, with nine black longitudinal lines on sides, extending from eye and breast back toward caudal peduncle; the fins are all concolorous and unmarked.

Here described from two specimens, 59 and 48 millimeters in length, collected by me on the reef at Bungau, Sulu Province.

GALLIONYMUS SPLENDIDUS Herre sp. nov. Plate 2.

Dorsal IV, 8; anal I, 7; pectoral 30; caudal 10.

Body stout, robust, wedge-shaped when viewed from above, the depth a trifle more than 4 times in the length, head very broad, its length 3 times in total length, its breadth four-fifths of its own length; the large eye equals the length of the narrow pointed snout and the width of the somewhat concave interorbital space; the stout preopercular spine contained 3 times in head; it terminates in three strong spines, the terminal one slenderer and straighter than the two anterior to it; the lower edge of spine smooth; the small circular gill opening is below and a little posterior to origin of lateral line.

The filamentous first dorsal spine reaches to base of last dorsal ray when depressed, and is contained 2.25 times in the total length; the other spines short, barely reaching origin of second dorsal when depressed, the second spine $1\frac{1}{3}$ times in head, the third spine almost as long, the fourth much shorter; second dorsal low, the rays of the posterior half more elevated than the anterior rays, except the last one which is low, reaching base of caudal when depressed, slightly greater than the depth, 3.75 times in the length, 1.25 times in the head; the two anterior and last anal rays shortest, the others of nearly equal length, equal to second dorsal in height and extending beyond base of caudal when depressed; the depth of the caudal peduncle is 5.625 times in the total length, its own length $\frac{7}{8}$ of its depth; caudal subtruncate, the lower rays longest, a little longer than head; the very broad pectoral equals the depth and is $1\frac{1}{4}$ of the length of the head; the ventrals are somewhat pointed and extend back beyond origin of anal, but are shorter than the pectorals.

In life this bizarre little fish is most gorgeously and brilliantly colored. The ground color of the body is reddish brown, the head, trunk, and soft dorsal are covered with broad irregular bands of intensely brilliant green, the transverse bands on top of the head and between the eyes margined with black; a large deep indigo blue circular spot on belly between pectorals; a blue area on side of head between the eye, preopercular spine, and ventral sprinkled with brilliantly shining golden spots; top of head and throat pale yellowish; a large green ocellus, margined by a broad blue band on the spinous dorsal between second and fourth spines, the fin above this blue-black; the ground color of second dorsal dusky to blackish; the caudal has a broad terminal band of green, the rays are green, the membranes pale or yellowish with longitudinal spots and lines of deep blue; the anal

and ventrals dusky with irregular bands of deep blue; pectoral green with a broad basal crossbar of deep blue, eye blue, with a golden ring about the pupil.

In alcohol the green fades to blue or disappears; golden lines crossing the throat and breast from side to side, and not mentioned above, are changed to pinkish violet.

Here described from the type and only specimen, 45 millimeters long, collected by me on a coral reef at Bungau, in about 2 fathoms of water. A Samal datu, the headman of the village, when this extraordinary and fantastically marked little creature was placed in his hand, said; "I never saw anything like that before." It excited greater interest than I ever saw those keen-eyed observers, the Samals, display in a fish.

Splendidus, glittering, brilliant.

ILLUSTRATIONS

PLATE 1. *Mirolabrichthys tuka* Herre and Montalban sp. nov. \times 1.5.
(Drawing by M. L. Nievera.)

2. *Callionymus splendidus* Herre sp. nov. (Drawing by P. Bravo.)

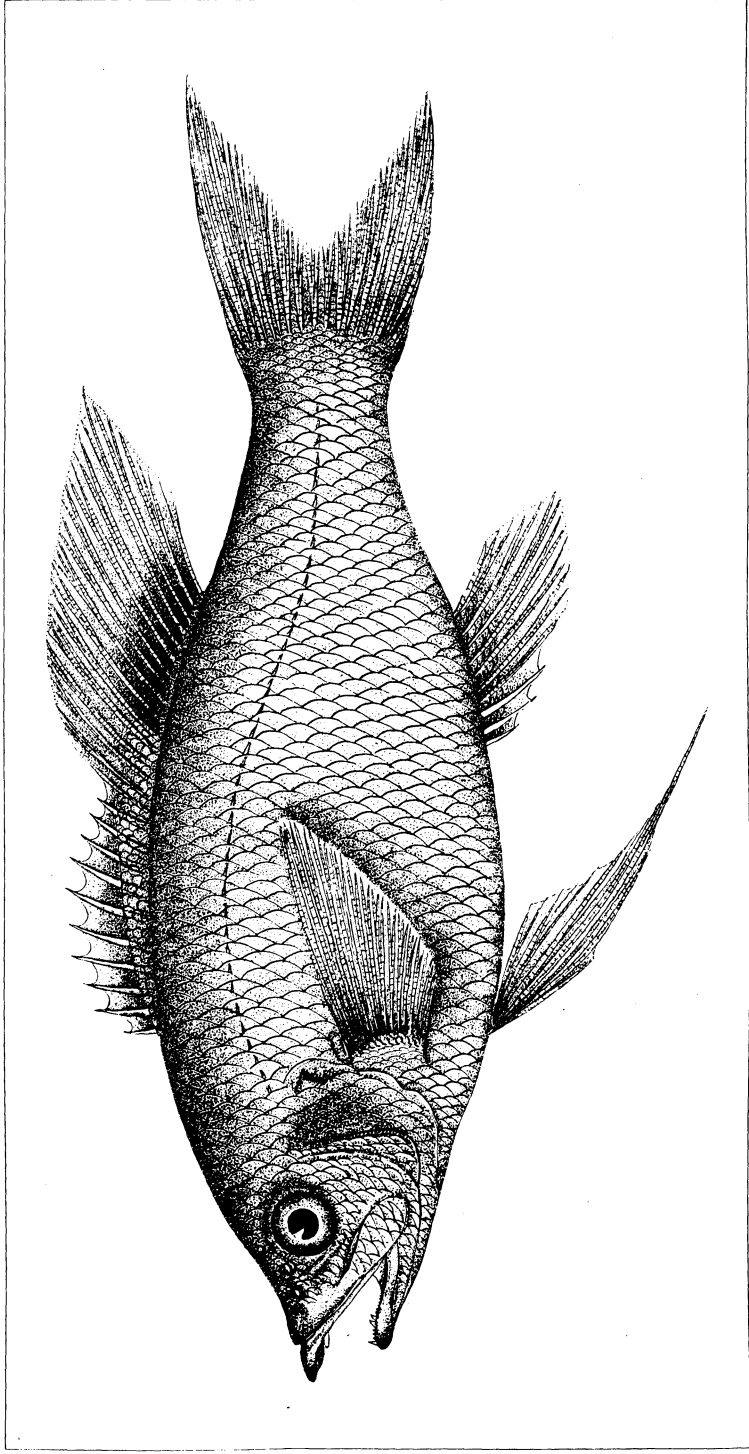


PLATE I. MIOLABRICHTHYS TUKA HERRE AND MONTALBAN G. AND SP. NOV.

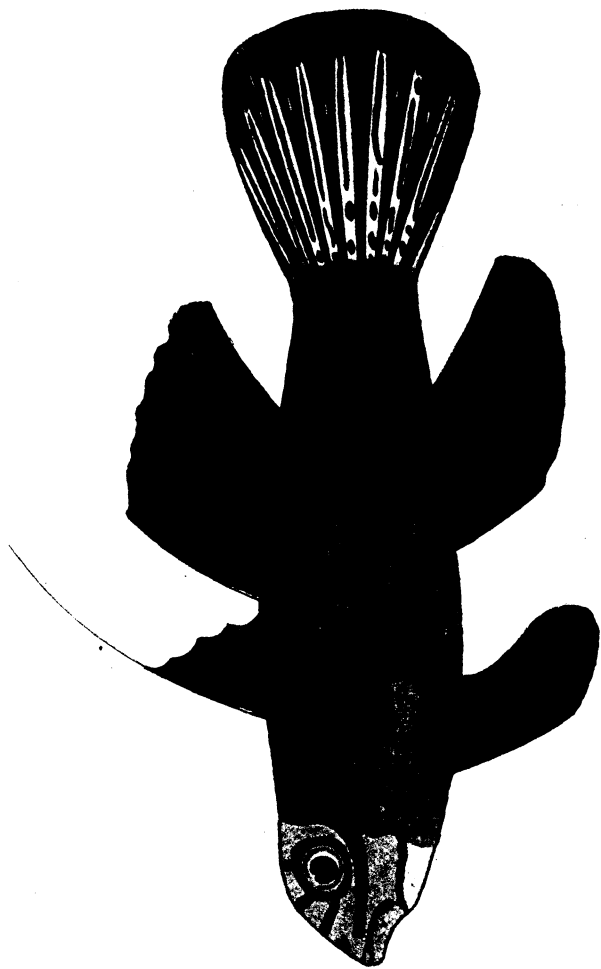


PLATE 2. CALLIONYMUS SPLENDIDUS HERRE SP. NOV.

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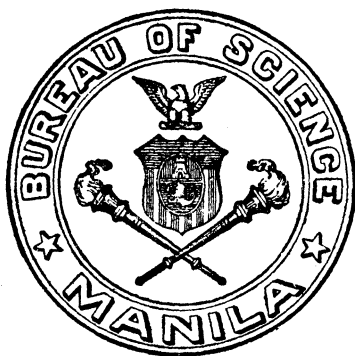
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APRIL, 1927

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THE PHILIPPINE JOURNAL OF SCIENCE

VOL. 32

APRIL, 1927

No. 4

CONCRETE VALUE OF PHILIPPINE SAND, GRAVEL AND CRUSHED STONE

By R. H. AGUILAR

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FOUR TEXT FIGURES

INTRODUCTION

In view of the constantly increasing volume of concrete construction work in the Philippine Islands, greater interest is now felt in and more attention paid by engineers and contractors engaged in concrete work to the quantity and quality of the sand, gravel, and stone deposits of the country. Systematic and reliable data on the possible extent of these natural deposits, and the comparative concrete value of the materials will no doubt be of interest.

CONCRETE MATERIALS

Concrete is essentially made up of cement, sand, gravel or crushed stone (or mixtures of both), and water with which the materials are thoroughly incorporated. Its most important constituent is cement, ordinarily Portland or natural cement. In the Philippine Islands, Portland cement is exclusively used on all concrete construction work, and its efficiency as binding material is determined according to Circular 33 of the United States Bureau of Standards. Next in importance is sand.

Sand¹ in its commonly accepted sense, is a fine aggregate derived from a natural source, all of which will pass, when dry, a screen having circular opening $\frac{1}{4}$ inch in diameter.

¹ Proc. Am. Soc. of Testing Materials 20 (1920) 137.

In the Philippine Islands, sand deposits are ordinarily found at the seashore and in river beds. Rocks can be quarried and crushed by mechanical means, and all particles that pass through $\frac{1}{4}$ -inch openings can be considered sand. The use of this material in actual practice, however, has been very limited; in some cases it is only used as a substitute for a portion of the natural sand.

Gravel is defined by Dake ² as "any aggregate of rock particles, coarser than sand and finer than boulders."

In concrete construction work this definition would be incomplete unless the size of the pebbles were specified. It is common engineering practice to limit the maximum size of the broken stone or gravel to 2.5 inches.³ Furthermore, in selecting the size of stone or gravel, various factors must be taken into consideration; such as thickness of the concrete section, proximity to the reënforcements, size and spacing of the reënforcements, etc. Reid ⁴ states the following:

In reinforced concrete, the broken stone or screened gravel for the concrete surrounding the reinforcement ought never be larger than will pass a $\frac{1}{2}$ inch screen when the reinforcement is small, or spaced close together or when placed near the surface. When larger sections are employed the stone may be increased in size, but should not exceed what will pass a $1\frac{1}{2}$ inch screen.

Broken stone, as its name indicates, is the product obtained by mechanical crushing of rocks or bowlders.

It used to be a common belief among practicing engineers that broken stone produces better concrete than does gravel, owing to the angular shape of the individual fragments. In this connection it is interesting to note the comparative crushing strengths given below of basaltic broken stone of good quality from Talim Island, Rizal Province, and two samples of gravel, one dark brown diorite from Pasig River, Rizal Province, and the other of a basaltic nature from Santa Cruz, Laguna Province.

Specimen.	Crushing strength, in pounds per square inch.
Gravel, from Santa Cruz, Laguna Province	3,027
Stone, from Talim Island, Rizal Province	2,834
Gravel, from Pasig River, Rizal Province	2,404

² The sand and Gravel Resources of Missouri, Missouri Bureau of Geology and Mines II 15 (1918) 1.

³ Taylor, F. W., and E. S. Thomson, Concrete, Plain and Reinforced, 3d ed., New York, John Wiley and Sons (1916) 13.

⁴ Concrete and Reinforced Concrete Construction, New York, The Myron C. Clark Publishing Co. (1907) 44.

The proportion of the mixture in each case was 1 : 2 : 4 by volume, and the sand used, although from different sources, was of basaltic and andesitic origin of similar granulometric composition.

It is also interesting to note the seemingly conflicting opinions of certain authorities on this matter.

Taylor and Thomson⁵ say:

Comparative tests of concrete made with broken stone and with gravel, in the same proportions by volume, show almost always that concrete made from hard broken stone, such as trap, gives higher compressive strength than concrete made from gravel. This appears to be the rule, not only when the materials are mixed by measured volumes, regardless of the percentages of void, but also when the broken stone and gravel are each screened to substantially the same size.

Reid,⁶ on the other hand, expresses himself in the following words:

There is no ground for believing that rounded stone or rounded sand gives less strength with cement than materials composed of angular fragments.

The results shown above and the apparent conflicting opinions of authorities on the subject seem to lead to the conclusion that both gravel and broken stone have certain advantages and disadvantages. Gravel, on account of its rounded form, readily slips into place in concrete, thus reducing the volume to a minimum and forming a compact mass of higher density. On the other hand, the rough surface of the broken stone usually causes greater adhesive strength to develop than does the smooth surface of the gravel, which to a certain extent counterbalances the porosity and the relative lower density of the broken-stone concrete. Accordingly, a good hard and dense gravel is perfectly comparable as concrete material with a good broken stone and vice versa; and, if a poor gravel and a good broken stone are both available in a locality, they should be mixed in such proportion as to improve the concrete value of the former. As a matter of fact, a mixture of equal parts of Pasig River gravel and Talim Island broken stone was used in the construction of the Legislative Building in Manila.

⁵ Concrete, Plain and Reinforced, 1st ed., New York, John Wiley and Sons (1905) 271-272; 3d ed. (1916) 324.

⁶ Concrete and Reinforced Concrete Construction, New York, The Myron C. Clark Publishing Co. (1907) 43.

PREVIOUS WORK ON PHILIPPINE AGGREGATES

In 1909, Adams⁷ published an article on the sources and the nature of the sand, gravel, and stone deposits near the City of Manila. The granulometric composition and the relative strengths of a few specimens were briefly discussed. The testing of the materials was incomplete; but, as Adams stated, "is sufficient to show their relative efficiencies and to check the conclusions arrived at from the geologic examinations." So, the main object of the author was the study of the aggregates, from the geologic point of view.

A more extensive work was published by Reibling⁸ in 1910. At that time concrete construction in the Philippine Islands was not so highly developed as it is at present. As a matter of fact, in 1909, while Reibling's investigation was being carried out, only one hundred specimens of cement aggregate and concrete were submitted for test. Some of the results given were not reliable, in as much as the specimens tested were not prepared under the direct supervision of the Bureau of Science, but under the direction of the men in charge of the various construction works; for which reason, the much spoken of "human factor" was very much in evidence. In this connection, Reibling himself made the following statements:

Concrete cubes tested as per "Request No. 68328" gave erratic results which were attributed to excess of sand and to the poor grading of the gravel. * * *⁹

At another time, laboratory and field tests did not agree. * * *¹⁰

The facts above mentioned show the necessity of proper representative sampling and a uniform method for the treatment of concrete samples after they have been gauged. The same concrete preserved under different conditions will give variable results.

OBJECT OF THE PRESENT ARTICLE

In this article, all the routine tests on sand, gravel, and stone specimens made in the cement laboratory of the Bureau of Science, covering a period of more than fifteen years, are discussed from both the theoretical and the practical points of view. The samples were collected by engineers and contractors and forwarded to the laboratory to be tested. The results

⁷ Philip. Journ. Sci. § A 4 (1909) 463.

⁸ Philip. Journ. Sci. § A 5 (1910) 117.

⁹ Ibid. 129.

¹⁰ Ibid. 133.

served as the basis for judging the quality of the materials for construction purposes. It is a compilation of the most reliable data so far published on Philippine aggregates.

METHODS OF PROCEDURE

It is an accepted principle that the strength of concrete is mainly due to the following factors, namely:¹¹ The quality and quantity of cement; the kind, size, and strength of the aggregates; the thoroughness with which the ingredients are balanced; the method of mixing; and its age. Variation in any of these factors will no doubt influence the strength of the concrete.

In order to secure results that would be comparable with each other, uniform methods of procedure were adopted. Only cement of good quality was used; the same proportional quantity was mixed with the sand and gravel samples; the ingredients were thoroughly balanced; fixed methods of gauging, mixing, and moulding were followed; and the moulded concrete specimens were invariably tested at the age of twenty-eight days. So the only variable factor was that which has reference to the quality of the aggregates.

According to Taylor and Thomson,¹²

There are two fundamental laws of strength which apply to mortars and concrete composed of the same cement with different proportion and sizes of sand and gravel.

(1) With the same aggregate, the strongest and most impermeable mortar is that containing the largest percentage of cement in a given volume of the mortar.

(2) With the same percentage of cement in a given volume of mortar, the strongest, and usually the most impermeable, mortar is that which has the greatest density, that is, which in a unit volume has the largest percentage of solid materials.

The first of these laws is understood by ordinary users of cement, but the second states a fact which is appreciated only by experts.

It is in connection with the second law that different authorities on concrete have made exhaustive studies, have written volumes of their experiences, and have even developed formulæ

¹¹ Reid, H. A., *Concrete and Reinforced Concrete Construction*, New York, The Myron C. Clark Publishing Co. (1907) 185. Similar factors are given by F. W. Taylor and S. E. Thomson, *Concrete, Plain and Reinforced*, 3d ed., New York, John Wiley and Sons (1916) 310.

¹² *Concrete, Plain and Reinforced*, 3d ed., New York, John Wiley and Sons (1916) 144.

and rules tending to reduce the pore space to a minimum to obtain the largest percentage of solid material per unit volume of concrete. The greatest handicap to the general practical application of these rules and formulæ is the large variety of materials that come under the denomination of aggregates.

The quality of the aggregates depends mainly upon three factors; namely, the geologic character of the rocks from which they are derived, the degree of chemical weathering, and the

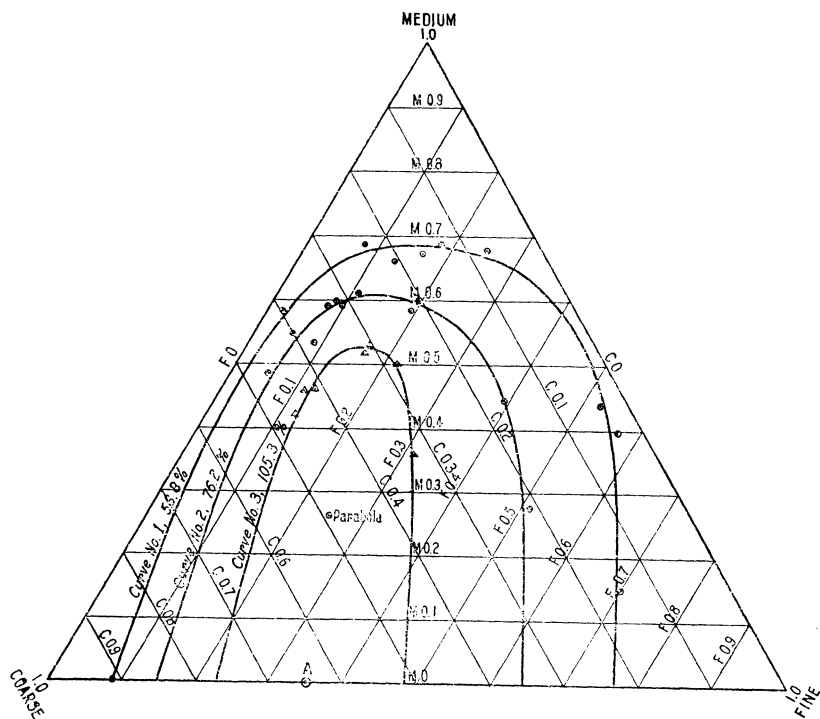


FIG. 1. Tensile-strength curves computed on the basis of the tensile strength of standard Ottawa sand as 100 per cent.

granulometric composition. It is not within human power to change the geologic character and the degree of chemical weathering of any sand or gravel deposit; but the granulometric composition can be so adjusted as to obtain arbitrarily graded particles which, when mixed with cement, will produce mortar and concrete of the greatest density, containing the largest percentage of solid material per unit volume.

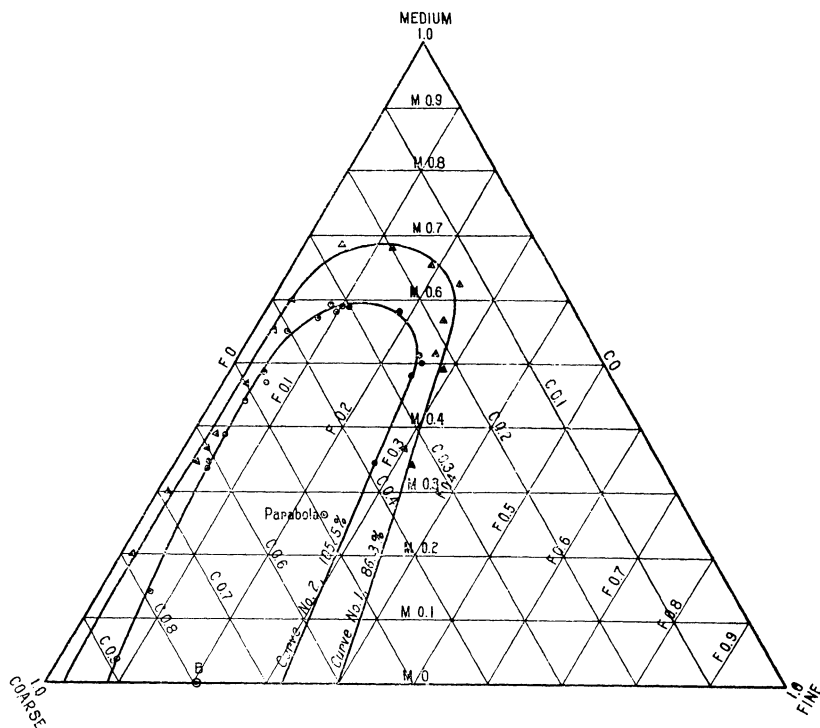


FIG. 2. Compressive-strength curves computed on the basis of the compressive strength of standard Ottawa sand as 100 per cent.

Feret, as long ago as 1892, after having made an extensive study on the mortar value of sand, arrived at the following conclusion:

The plastic mortars, which per unit volume, contain the greatest absolute volume of solid materials (cement + sand) are those in which there are no medium grains, and in which coarse grains are found in proportion double to that of fine grains, cement included.¹³

How much practical truth there is in this statement is illustrated in figs. 1 and 2. Each triangle represents Feret's¹⁴ three-screen method of granulometric sand analysis and each point shows the granulometric composition of a sand specimen. All sand particles that pass through a 0.2-inch opening but are retained on No. 15 mesh are considered coarse; those that pass

¹³ Ibid. (1905) 147; (1916) 161.

¹⁴ Ibid. (1905) 145-156; (1916) 159-160.

No. 15 but are retained on No. 50, medium; and those that pass No. 50 are considered fine.¹⁵

The series of curves are loci of points representing sand samples of different granulometric composition, but which possess practically the same tensile and compressive strengths as shown in Tables 1 to 5.

From the general direction of the contour of the curves of which the inner ones represent higher tensile and compressive strengths than do the outer ones, it is possible to conceive a theoretical value of maximum strength, indicated by point A in fig. 1 and point B in fig. 2, representing the granulometric composition of sands composed of coarse and fine particles only but no medium particles. In these figures, however, the cement has not been included with the fine particles.

To substantiate this conclusion, mortar specimens were prepared for tensile and compressive strength tests, using Pasig River sand of uniform quality as to degree of hardness and mineralogic composition. The physical characters of the sample and the data on the sand-mortar specimens are as follows: Specific gravity, 2.5; percentage of voids, 29.6.

Granulometric composition.

Screen No.	Particles passing through. Per cent.
4	100
10	58
20	32
30	18
40	10
50	6
80	4
100	3
200	2

¹⁵ The sieves used conform with the United States Bureau of Standard specifications as published in Proc. Am. Soc. of Testing Materials I 24 (1924) 719:

Commercial No. of sieve.	Size of openings.	
	Inch.	mm.
10	0.0787	1.999
20	0.0331	0.841
30	0.0232	0.589
40	0.0165	0.419
50	0.0117	0.297
60	0.0098	0.249
80	0.0070	0.178
100	0.0059	0.149
200	0.0029	0.074

TABLE 1.—Sand specimens having an average tensile strength of 56.8 per cent on the basis of standard Ottawa sand as 100.

Province.	Town.	Location of deposit.	Geologic classification.	Laboratory No.	Three-screen analysis.			Tensile strength. Sand specimen Ottawa sand $\times 100$.
					Coarse.	Medium.	Fine.	
Batangas.....	San Luis.....	Beach.....	Volcanic sand.....	146593	4	40	56	57.4
Benguet.....	Baguio.....	Government Center.....	Mostly silica.....	150866	15	15	70	58.0
Bohol.....	Palo.....	Seashore.....	Mostly quartz.....	145397	3	44	53	57.7
Bulacan.....	Pullian.....	Pullian River.....	Basic volcanic rock.....	144591	7	69	24	55.0
Cavite.....	General Trias.....	Malabon River.....	Vesicular lava and some quartz	151029	14	69	17	59.4
Leyte.....	Palo.....	Malirong River.....	Basaltic sand.....	147651	16	68	16	59.0
Maabate.....	Milagros.....	Lumbang River.....	Andesitic and basaltic.....	149505	25	68	7	55.5
Mindanao.....	Jolo.....	Caldera Bay.....	Basaltic and some quartz.....	148237	40	58	2	55.6
Occidental Negros.....	Isabela.....	Binalbagan River.....	Andesitic and basaltic.....	153663	21	66	13	54.0

TABLE 2.—*Sand specimens having an average tensile strength of 76.2 per cent on the basis of standard Ottawa sand as 100.*

Province.	Town.	Location of deposit.	Geologic classification.	Laboratory No.	Three-screen analysis.			Tensile strength. Sand specimen Ottawa sand $\times 100$.
					Coarse.	Me- dium.	Fine.	
Albay.....	Camalig.....	Cabaran River.....	Basaltic and andesitic.....	119543	23	58	19	76.0
Antique.....	Ipil.....	Bungul River.....	Andesitic.....	120183	21	60	19	71.8
Batangas.....	Santo Tomas.....	Tanawan River.....	Basaltic.....	147007	28	61	11	75.3
Bohol.....	Calape.....	Talisay shore.....	Andesitic.....	145445	16	46	38	72.8
Cavite.....	Kawit.....	Rio Grande.....	Igneous sand.....	122314	56	36	8	79.5
Do.....	Noveleta.....	Noveleta River.....	Basaltic.....	149506	40	55	5	78.0
Cebu.....	Daan Bantayan.....	Beach.....	Coralline.....	143761	33	59	8	73.0
Do.....	Poro.....	do.....	do.....	154356	34	59	7	78.0
Laguna.....	Santa Cruz.....	Malunod River.....	Basaltic.....	142380	32	59	9	78.0
Leyte.....	Tabontabon.....	do.....	Magnetite and quartz.....	121416	21	27	52	78.0
Oriental Negros.....	Bais.....	Bais River.....	Coralline.....	122046	38	53	9	77.7
Tayabas.....	Tayabas.....	Alitao River.....	Basaltic and andesitic.....	152450	47	48	5	77.0

TABLE 3.—*Sand specimens having an average tensile strength of 105.3 per cent on the basis of standard Ottawa sand as 100.*

Province	Town.	Location of deposit.	Geologic classification.	Laboratory No.	Three-screen analysis.			Tensile strength. Sand specimen Ottawa sand $\times 100$.
					Coarse.	Me- dium.	Fine.	
Cebu.....	Carcar.....	Mananga River.....	Basaltic.....	147129	28	50	22	110
Laguna.....	San Pablo.....	Bafadero River.....	Andesitic, diorite.....	142608	30	53	17	105
Mindanao.....	Jolo.....	Baliwasan beach.....	Basaltic and coralline.....	148237	46	42	12	100
Do.....	Zamboanga.....	do.....	do.....	127041	32	52	16	107
Romblon.....	Romblon.....	Seashore.....	Coralline.....	144888	34	34	32	104
Samar.....	Borongan.....	Sunco beach.....	Andesitic basaltic.....	151148	41	46	13	100
Tayabas.....	Sariaya.....	Munting River.....	Basaltic.....	128700	43	46	11	111

TABLE 4.—Sand specimens having an average compressive strength of 86.3 per cent on the basis of standard Ottawa sand as 100.

Province.	Town.	Location of deposit.	Geologic classification.	Laboratory No.	Three-screen analysis.			Compressive strength. Sand specimen Ottawa sand
					Coarse.	Medium.	Fine.	
Bataan.....	Orani.....	Orani River.....	Andesitic.....	145278	19	58	23	80.7
Batangas.....	Bauang.....	Bauang River.....	Basaltic.....	150352	62	34	4	90.4
Bulacan.....	Calumpit.....	Calumpit River.....	Volcanic rock.....	144857	27	68	5	87.0
Cavite.....	Kawit.....	Imus River.....	Mostly basalt and scoria.....	122314	78	20	2	87.0
Do.....	do.....	Rio Grande.....	Partially weathered volcanic rock.....	123443	58	38	4	88.6
Do.....	do.....	do.....	Volcanic.....	123521	60	36	4	89.5
Do.....	Noveleta.....	San Juan River.....	Scoriaceous basalt.....	125977	68	30	2	84.0
Cebu.....	Pinamugahan.....	Beach.....	Mostly quartz.....	144970	37	60	3	82.6
Ilocos Sur.....	Candon.....	Santa Cruz River.....	Andesitic and basaltic.....	151978	16	65	19	80.0
Iloilo.....	San Miguel.....	Aganao River.....	Magnetite and quartz.....	144087	23	52	25	86.0
Laguna.....	Pagsanjan.....	Pagsanjan River.....	Basaltic rocks.....	128903	43	54	3	87.1
Do.....	Santa Cruz.....	Santa Cruz River.....	Basaltic and andesitic.....	149829	50	46	4	89.5
Leyte.....	Alang-Alang.....	Dap-Dap River.....	Basaltic and magnetite.....	147651 A	23	49	28	85.7
Do.....	Dagani.....	Guinarona River.....	Basaltic rocks.....	147651 B	34	37	29	88.7
Pampanga.....	Magalang.....	Quitangil River.....	Volcanic.....	146671	13	63	24	86.8
Pangasinan.....	San Jacinto.....	San Jacinto River.....	Andesitic.....	145666	20	68	12	89.8
Romblon.....	Romblon.....	Seashore.....	Coraline.....	144383	34	34	32	84.0

TABLE 5.—Sand specimens having an average compressive strength of 105.5 per cent on the basis of standard Ottawa sand as 100.

Province.	Town.	Location of deposit.	Geologic classification.	Laboratory No.	Three-screen analysis.			Compressive strength. Sand specimen \times 100. Ottawa sand
					Coarse.	Medium.	Fine.	
Albay.....	Malinao.....	Quilani River.....	Volcanic.....	119707	33	57	10	105
Antique.....	Ipil.....	Ipil River.....	Andesitic.....	120133B	38	35	27	110
Do.....	Sibalom.....	Sibalom River.....	Andesitic and basaltic.....	151980	37	56	7	103
Do.....	Valderrama.....	Caranigan River.....	Mostly andesitic.....	120133C	27	48	25	108
Cebu.....	Cebu.....	Guadalupe River.....	Andesitic.....	144671	61	34	5	101
Do.....	do.....	Guadalupe.....	Basic volcanic rocks.....	145380	31	58	11	106
Ilocos Norte.....	Vintar.....	Laog River.....	Andesitic and basaltic.....	151190	52	43	5	109
Iloilo.....	San Miguel.....	Oton beach.....	Basaltic dioritic.....	145780	24	51	25	102
Laguna.....	Los Baños.....	Laguna de Bay at Bayog.	Basaltic.....	86085A	41	54	5	105
Do.....	do.....	Laguna de Bay at Mayondon.	do.....	86085B	48	46	6	100
Mindanao.....	Zamboanga.....	Tumaga River.....	Basaltic andesitic.....	122303B	79	14	7	107
Occidental Negros.....	Maao.....	Maragandang River.....	Andesitic.....	150748	24	50	26	106
Rizal.....	McKinley.....	Pasig River.....	do.....	145643C	25	58	17	100
Do.....	do.....	do.....	do.....	145643D	32	58	10	103
Do.....	Pasig.....	do.....	Basaltic and andesitic.....	154012	57	38	5	109
Sorsogon.....	Sorsogon.....	Lantu River.....	Andesitic and dioritic.....	154358	34	58	8	108
Tarlac.....	Capaz.....	Sanctiago River.....	Volcanic rock and quartz.....	123447	62	33	5	108
Tayabas.....	Tayabas.....	Altiao River.....	Basaltic and andesitic.....	152450	47	48	5	109

SAND-MORTAR SPECIMENS

S₁—A portion of the sample of sand was made into test specimens as received.

S₂—Another portion was screened into sizes of the following granulometric composition: 63 per cent passing No. 4 screen (about 0.2-inch opening) but retained on No. 15 screen, and the rest, 37 per cent, passing No. 50 screen. According to the Feret three-screen method of sand analysis, this specimen is composed of coarse and fine particles only and no medium particles.

S₃—A third portion was screened into several parts according to sizes, and the proportional quantities so obtained were adjusted to form a combined specimen having a well-graded granulometric composition curve similar to a parabola.

Test specimens using standard Ottawa sand were also prepared for purposes of comparison. The results are shown in Table 6.

TABLE 6.—*Influence of the granulometric composition of sands upon the strength of mortars.*

[Age of test specimens, 28 days.]

Item.	Proportion by weight.	Per cent granulometric analysis on the basis of Feret's three-screen method.			Weight of mortars at test in pounds per cubic foot. ^a	Per cent water of the dry mixture by weight.	Per cent void of the dry sand.	Average strength in pounds per square inch.	
		Coarse.	Medium.	Fine.				Tensile. ^a	Compressive. ^a
Ottawa----	1 : 3	0	100	0	146	13.0	34.4	433	3,718
S ₁ -----	1 : 3	57	37	6	153	13.1	29.6	452	4,762
S ₂ -----	1 : 3	63	0	37	151	13.5	32.9	487	4,902
S ₃ -----	1 : 3	48	24	28	148	13.3	30.5	422	4,092

^a The figures represent the average weight and strength of sixteen specimens.

The conclusion arrived at, that the theoretical points A and B (figs. 1 and 2), like those of Feret, are points of maximum strength, has been substantiated in this particular case. It should be noted, however, that mortar specimens under item S₁, which were prepared from the sample of sand as received, appear to be denser and nearly as strong as those under item S₂, which were prepared from sand composed of coarse and fine particles only. Mortar specimens under item S₃ appear to possess lower strength and lower density than do those under items S₁ and S₂, indicating that the parabola is not the ideal granulometric composition curve of a sand of the highest density and strength.

Generalizing the results of tests shown in Table 8, wherein the strengths of sand mortars composed of sand of widely different geologic characters and variable granulometric composition are compared with the strength of standard Ottawa sand mortar (considering the latter as 100), it is possible to arrive at another conclusion somewhat different from that of Feret.

In fig. 3, two curves were drawn; namely, curve 1 and curve 2. Each point in curve 1 represents the average percentage of coarse particles of the sand specimens shown in Table 8, corresponding to a given compressive strength. Similarly, each point in curve 2 represents the corresponding percentage of

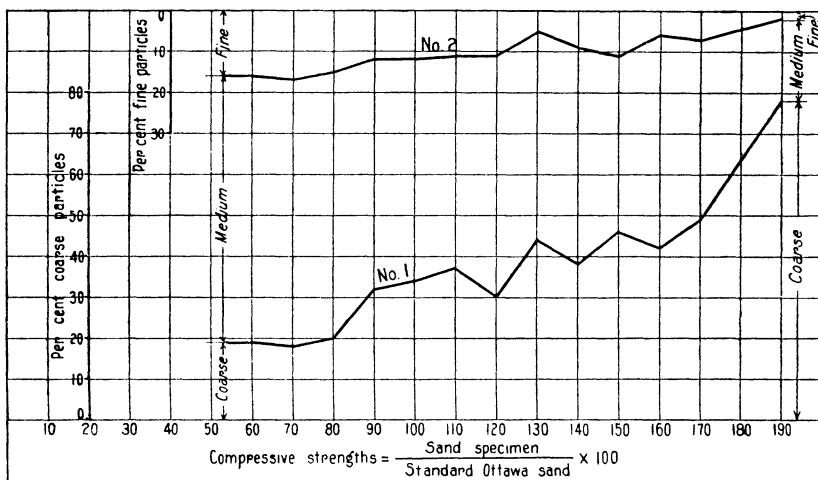


FIG. 3. Relation between compressive strength and the percentage of coarse, medium, and fine particles, representing the granulometric composition of sands.

fine particles of the same sand specimens. The vertical distance between the two curves represents the percentage of medium particles. Curve 1 may also be considered as the line of demarcation between the coarse and the medium particles, and curve 2, the line of demarcation between the medium and the fine particles.

It is apparent from the general direction of the curves that, as the comparative compressive strength increases, the proportion of coarse particles also increases, while the proportion of medium and fine particles decreases to a minimum. The general results, therefore, seem to point to the conclusion that

the theoretical point of maximum strength represents a uniformly graded sand composed of coarse particles with practically no fine and with the smallest amount of medium particles. In other words, sand mortars possessing exceptionally high strength are composed almost entirely of coarse sand and cement. Coarse sand is understood to be all particles that pass through a 0.2-inch opening and are retained on No. 15 mesh.

Between this conclusion and Feret's certain similarities and differences are observed; namely, both admit that the point of maximum strength represents the granulometric composition of a mortar composed of coarse and fine particles only, cement included, without medium particles. Feret's conclusion, however, admits of fine particles of sand with cement, while that drawn from fig. 3 does not admit of fine particles of sand, the cement taking its place entirely. Both conclusions appear to be applicable to sands of widely different geologic nature.

CONCRETE

In reference to the application to concrete of the second law of strength the results obtained by William B. Fuller¹⁶ from a series of tests made in this connection, compared with the general results of tests shown in Table 9, are of interest. Fuller's¹⁷ original theory was stated as follows:

The experience which the writer has had and the various experiments which he has made indicate that concrete which works the smoothest in placing and gives the highest breaking strength for a given percentage of cement is made from an aggregate whose mechanical analysis taken after mixing the sand and the stone forms a curve approaching that of a parabola, with its beginning at zero coördinates (o) and passing through the intersection of the curve of the coarsest stone with the 100% line, that is, passing through the upper end of the coarsest stone curve.

This conclusion is based upon the comparative transverse strengths of concrete beams. Although no definite relationship exists between transverse strength and compressive strength, yet for practical purposes either method of testing can be adopted for comparing the relative strength of different materials.

Later experiments performed by the same author indicate that the curve of maximum density and strength is more accu-

¹⁶ Taylor, F. W., and S. E. Thomson, *Concrete, Plain and Reinforced*, 3d ed., New York, John Wiley and Sons (1916) 192.

¹⁷ Taylor, F. W., and S. E. Thomson, *Concrete, Plain and Reinforced*, 1st ed., New York, John Wiley and Sons (1905) 195.

rately defined as the combination of an ellipse and a straight line than as a parabola.¹⁸

The ellipse-straight-line combination curve, however, represents the granulometric composition of the mixture of sand, gravel or stone, including cement, while the parabolic curve,¹⁹ as above stated, represents the mixture of sand and stone, excluding cement.

By generalizing the results of concrete tests shown in Table 9 (that is, taking average values of the mechanical analyses of the sand and gravel, arbitrarily grouped according to their compressive strength), tabulating the values so obtained, and plotting the mechanical analysis curves of the gravel, some interesting conclusions may be drawn.

In Table 7 under the last column the three-screen method of presenting the mechanical analyses of gravel, similar to that of Feret, has been adopted. This is a very convenient means of discussing the general results of the tests. The different arbitrary limiting values adopted for coarse, medium, and fine sizes are as follows:

Coarse sizes are those passing holes 3 inches in diameter and retained on holes of 1.5 inches; medium sizes are those passing holes 1.5 inches in diameter and retained on holes 0.67 inch; and fine sizes are those passing holes 0.67 inch in diameter and retained on holes 0.2 inch.²⁰

¹⁸ Taylor, F. W., and S. E. Thomson, *Concrete, Plain and Reinforced*, 3d ed., New York, John Wiley and Sons (1916) 192-198.

¹⁹ Taylor, F. W., and S. E. Thomson, *Concrete, Plain and Reinforced*, 1st ed., New York, John Wiley and Sons (1905) 194-209; 3d ed. (1916), Appendix I, 849-855.

Construction of the Parabola.

If D=Largest diameter of stone.

d=Any given diameter.

P=Per cent mixture smaller than any given diameter.

The equation of the parabola would be

$$d = \frac{P^2 D}{10,000}$$

²⁰ Feret's limiting values are as follows: Coarse, passing holes of 6 centimeters (2.36 inches) diameter and retained by holes of 4 centimeters (1.57 inches) diameter; medium, passing holes of 4 centimeters (1.57 inches) diameter and retained by holes of 2 centimeters (0.79 inch) diameter; fine, passing holes of 2 centimeters (0.79 inch) diameter and retained by holes of 1 centimeter (0.39 inch).

TABLE 7.—*Relation between the compressive strength of concrete and the mechanical analysis of the aggregates.*

[C, coarse; M, medium; F, fine. Figures express percentage composition.]

No.	Strength, pounds per square inch, 28 days.	Three-screen granulometric composition of sand.			Mechanical analysis of gravels; per cent sizes passing through various circular openings; diameters in inches.			
		C	M	F	3.00	2.25	1.50	1.00
1.....	1,000-1,500	22.0	56.7	21.3	100	99.3	87.4	44.8
2.....	1,500-2,000	28.2	59.3	12.5	100	98.3	83.2	49.8
3.....	2,000-2,500	30.9	56.7	12.4	100	99.4	75.7	42.9
4.....	2,500-3,000	40.4	46.6	13.0	100	95.8	71.6	28.2
5.....	3,000-3,500	41.0	49.6	9.4	100	99.2	78.5	32.4

No.	Strength, pounds per square inch, 28 days	Mechanical analysis of gravels; per cent sizes passing through various circular openings, diameter in inches.					Three-screen method of mechanical analysis of gravel.		
		0.67	0.45	0.30	0.20	0.15	C	M	F
1.....	1,000-1,500	26.3	16.5	13.8	11.6	3.5	13	61	26
2.....	1,500-2,000	30.0	16.1	13.3	7.1	5.5	17	53	30
3.....	2,000-2,500	21.7	9.0	3.1	3.1	3.0	24	54	22
4.....	2,500-3,000	9.8	1.9	0.5	0.4	0.1	28	62	10
5.....	3,000-3,500	16.3	6.6	4.8	0.8	0.1	22	62	16

The results shown in Table 7 under the second column reaffirm the conclusion arrived at for sand; namely, the larger the quantity of coarse particles of a given specimen of sand, the higher its compressive strength, from which it naturally follows that coarse sand makes a good aggregate, both for mortar and for concrete.

From the average mechanical-analysis curves of gravels shown in fig. 4, the following general conclusion is apparent:

Gravels showing satisfactory compressive strengths are composed of not less than 22 per cent coarse sizes and not more than 22 per cent fine sizes, the rest consisting of medium sizes.

This conclusion appears to be satisfactorily applicable to Fuller's ²¹ ellipse-straight-line theory, ²² but it is not in accordance

²¹ Taylor, F. W., and S. E. Thomson, Concrete, Plain and Reinforced, 3d ed., New York, John Wiley and Sons (1916) 192-198.

²² The straight line shown in fig. 4 corresponds to the proportional quantity of gravel present in Fuller's ellipse-straight-line curve, which includes cement, sand, and gravel.

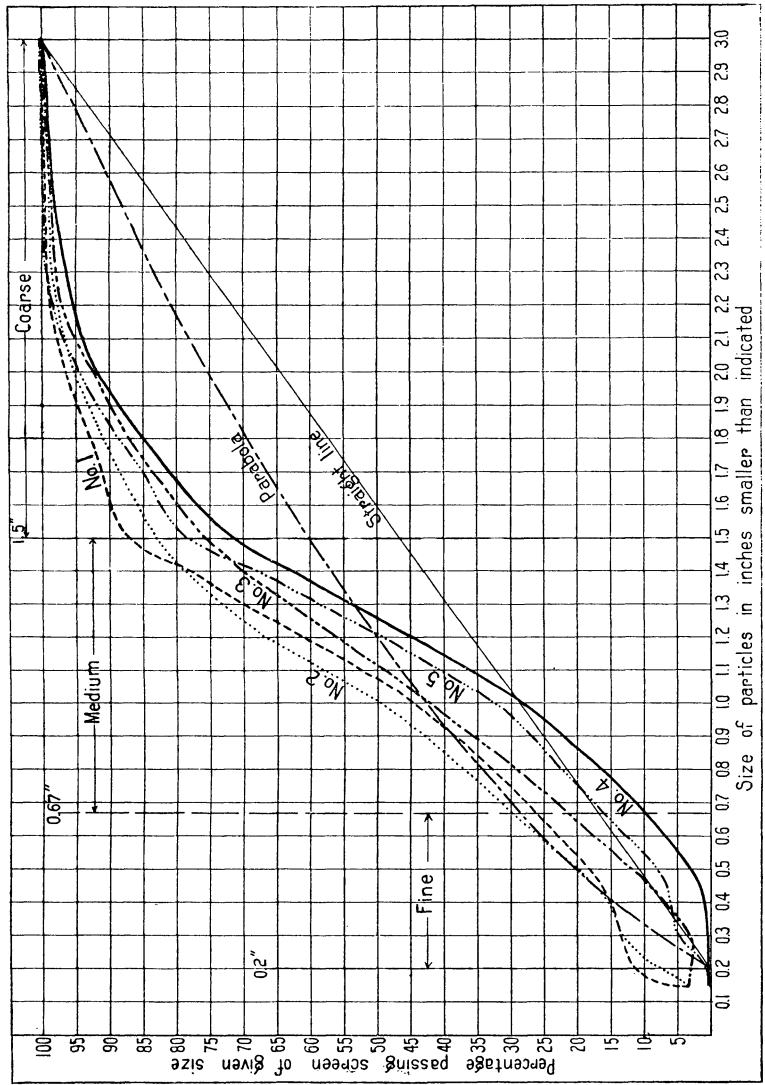


Fig. 4. Average mechanical analysis curves of gravels used in the testing of concrete specimens, grouped according to their compressive strengths as shown in Table 7.

with his parabolic curve.²³ The parabola in fig. 4 is above the 22 per cent limiting value for fine sizes of gravel; it consists of 40 per cent coarse sizes and 28.5 per cent fine sizes. The straight line, on the other hand, consists of 53.5 per cent coarse sizes and 17 per cent fine sizes.

In view of these results, it is safe to assume, for the time being, the practical truth of the following conclusion:

Under similar conditions of hardness and general geologic character, the nearer the mechanical-analysis curve of a gravel specimen approaches a straight line, the higher is the crushing strength of concrete made from this gravel; provided the cement used is of good quality and the sand is mainly composed of coarse particles with the smallest proportion of medium particles and with practically no fine particles.

RESULTS OF TESTS

The results of tests for sand and gravel are shown in Tables 8 and 9, respectively. They are grouped by provinces to facilitate the location of the deposits. Many of the specimens show low tensile and compressive strengths. Such materials were sent to the laboratory for comparative test only, but have not been actually used in construction work. The supervising engineers of the Bureau of Public Works have always taken the necessary precautions to see that a better grade of aggregates was used in all cases, oftentimes at great expense because of the cost of transporting adequate materials from the sources of supply to the site of the job.

In order that the tensile and compressive strengths of the various sands for seven and for twenty-eight days might be comparable with each other, independently of the variation in the quality of the cement used, they were compared with the tensile and compressive strengths of specimens made of the same cement and standard Ottawa sand on the basis of 100; the results shown in the last columns of Table 8 were computed in this manner.

The mixture for mortar was invariably in the proportion of 1 : 3 by weight for tensile and compressive strength; and for gravel 1 : 2 : 4 by volume, considering the weight of 1 cubic foot of cement to be 94 pounds. The form and size of the specimens for compressive strength were cubes 2 by 2 by 2

²³ The curve shown in fig. 4 is a portion of the parabola corresponding to the proportional quantity of gravel present in the mixture of sand and gravel.

inches and cylinders 3.54 by 7 inches for mortar, and 6 by 6 by 6 inches for concrete. Deviations from this method were noted.

The relation between the unit strength of sand mortars tested in the form of cubes and those tested in the form of cylinders cannot be precisely established; it has been found to be very variable. However, the following average compressive strengths of standard Ottawa sand mortar representing eighty-two cylinders and thirty-four cubes are given for purposes of information:

Age of specimens at test.	Compressive strengths in pounds per square inch.	
	Cylinders.	Cubes.
<i>Days.</i>		
7 -----	1,656	1,762
28 -----	2,468	3,134

The above results show that the cubes are 6.4 per cent stronger than the cylinders at the age of seven days, and 26.98 per cent stronger than the cylinders at the age of twenty-eight days.

It is apparent that the cubes attain their maximum strength much sooner than do the cylinders; as a matter of fact, the average increase in strength of the cylinders from seven to twenty-eight days is 49 per cent and that of the cubes, 78 per cent. The increase in strength varies, for cylinders, from 19 to 77 per cent; and for cubes, from 49 to 110 per cent.

According to Feret—²⁴

The form and dimensions of the specimen do not greatly influence the strength per unit area in compression when the height and width of the block are approximately equal.

In view of this conclusion, therefore, the above difference in the unit strength between cylinders and cubes should be attributed to the inequality of the width and height of the cylinders rather than to the difference in the size of the specimens tested, and cylindrical specimens having approximate dimensions of 7 inches in diameter by 7 inches in height would give nearly the same unit strength as the 2 by 2 by 2 inch specimens.

²⁴ Taylor, F. W., and S. E. Thomson, *Concrete, Plain and Reinforced*, 3d ed., New York, John Wiley and Sons (1916) 145.

All the tests shown in Tables 8 and 9 were performed in the cement laboratory of the Bureau of Science, under the direct supervision of W. C. Reibling, F. D. Reyes, A. W. King, and myself.

GENERAL GEOLOGIC CHARACTERS OF THE AGGREGATES

Most of the Philippine sands and gravels used for construction work are either andesitic or basaltic. This undoubtedly is due to the fact that nearly all the volcanic rocks of the Islands are andesitic, though basalts with variable amounts of olivine are also abundant.²⁵

Sand and gravel containing relatively greater percentages of feldspar are found in the beds of rivers that flow through Pangasinan, Tarlac, and Zambales Provinces. Many of these rivers derive their water from the northeastern and southwestern sections of the western cordillera. According to Smith,²⁶ the main sources of sands of this kind are feldspar porphyry of the same character as the rocks that compose Mount Pinatubo.

Sand and gravel of calcareous nature, consisting mainly of coralline limestone, are found in large quantities in Cebu, Bohol, and Romblon Provinces. According to Becker,²⁷ Cebu is covered for the most part by a mantel of coral a hundred or more feet in thickness, which reaches from the crest of the island to the sea; Smith²⁸ believes that the geologic formations of Bohol are similar to those of Cebu. A great deal of the sand used in Romblon is taken from Tablas Island at sitio Bantayan; both islands are largely of limestone formation.²⁹

The sand and gravel specimens from Cavite and Batangas are of a scoriaceous and tuffaceous nature, and show at a glance their volcanic origin. The rivers from which the materials were taken derive their waters from the mountains and ridges situated in the neighborhood of Taal Volcano, which are composed of volcanic ash and tuff deposits.³⁰

²⁵ Iddings, J. P., *Philip. Journ. Sci.* § A 5 (1910) 155.

²⁶ *Philip. Journ. Sci.* § A 4 (1909) 22-23.

²⁷ Report on the Geology of the Philippine Islands (1901) 19.

²⁸ Geology and Mineral Resources of the Philippine Islands, Bur. Sci. Pub. 19 (1924) 195.

²⁹ *Ibid.* 200.

³⁰ Adams, G. I., *Philip. Journ. Sci.* § A 5 (1910) 95.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands.*

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
1	Albay	Camalig	Cabaran River	A	Guinobatan-Jovellar bridges.	Pesos.	119643	Dec. 7, 1924	Basaltic and andesitic.
2	Do.	Daraga	Yawa River	U	Albay High School	1.50	149637	Jan. 4, 1924	Sharp-grained volcanic.
3	Do.	Malinao	Quinali River				119707	Jan. 25, 1915	Volcanic.
4	Do.	Oas	Creek, Legaspi-Agus road, kilometer 32.	A	Oas School building	2.00	157832	July 6, 1925	Vesicular lava.
5	Do.	do.	Creek, Legaspi-Agus road, kilometer 36.	A	do.	2.50	157833	do.	Slightly weathered vesicular basalt.
6	Do.	do.	Quinali River	U	do.	1.50	157382	June 9, 1925	Scoriaceous sand.
7	Do.	Polangui	Polangui River	U	Boracquit Bridge	2.00	145626	Feb. 3, 1923	Basaltic.
8	Do.	do.	do.		Libon Bridge on Quinal River.		120494	July 3, 1915	Andesitic, basaltic.
9	Antique		Bungol River		Bungol River Bridge		120133A	May 7, 1915	Andesitic.
10	Do.	Ipil	Ipil River		do.		120133B	do.	Do.
11	Do.	Sibalom	Magrancia beach	A	Sibalom-San José irrigation project.	1.00	154419A	Dec. 8, 1924	Andesitic and basaltic.
12	Do.	do.	do.	A	do.	1.00	154419B	do.	Do.
13	Do.	do.	Sibalom River	A	do.	1.00	152180A	Jan. 23, 1924	Do.
14	Do.	do.	do.	A	do.	1.00	152180B	do.	Do.
15	Do.	do.	do.	A	do.	1.00	151469	May 6, 1924	Do.
16	Do.	do.	do.	A	do.	1.00	151652	May 16, 1924	Do.
17	Do.	do.	do.	A	do.	1.00	151980	June 10, 1924	Andesitic and basaltic (washed).

18	Do.	do.	A	do.	1.00	151981	do.	Andesitic and basaltic (weathered).
19	Do.	do.	A	do.	1.00	152179A	June 23, 1924	Andesitic and basaltic.
20	Do.	do.	A	do.	1.00	152179B	do.	Andesitic, basaltic, and magnetite.
21	Do.	Valderrama	A	Bungol River Bridge		120133C	May 7, 1915	Andesitic.
22	Bataan	Balanga	U	Balanga Elementary School.	1.50	158269	July 31, 1925	Basaltic and feldspar.
23	Do.	Mariveles	A	Bureau of Navigation works.		117596	Oct. 2, 1913	Andesitic.
24	Do.	Orani		U. S. Army building.		94269	Nov. 17, 1911	Quartz and feldspar.
25	Do.	do.	U	Orani market.	2.00	144546	Nov. 11, 1922	Weathered dioritic.
26	Do.	do.	U	do.	2.00	144935	Dec. 6, 1922	Weathered andesitic.
27	Do.	do.	U	do.	4.00	145278A	Jan. 4, 1923	Andesitic.
28	Do.	do.	U	do.	3.00	145278B	do.	Do.
29	Do.	do.	U	do.	6.00	145278C	do.	Do.
30	Do.	Orion	U	Arellano Memorial School.	3.00	147304A	June 16, 1923	Feldspar.
31	Do.	do.	U	do.	2.50	147304B	do.	Feldspar and basaltic.
32	Do.	do.	U	do.	2.50	147304C	do.	Do.
33	Batangas	Batangas	A	Batangas Provincial Capitol.		158598	Aug. 22, 1925	Volcanic tuff.
34	Do.	do.	A	do.		158266	July 31, 1925	Do.
35	Do.	do.	A	do.		158671	Aug. 27, 1925	Do.
36	Do.	do.	A	do.		158610	Aug. 24, 1925	Do.
37	Do.	Bauan	A	Bauan waterworks		150352	Feb. 25, 1924	Basaltic.
38	Do.	Calaca	A	Calaca municipal building.		158311	Aug. 4, 1925	Volcanic tuff.
39	Do.	Rosario	L	Rosario waterworks.		159498	Oct. 21, 1925	Volcanic tuff, very much weathered.
40	Do.	do.	L	do.		158969	Sept. 16, 1925	Volcanic tuff.
41	Do.	San Luis	U	San Luis municipal building.	0.54	146593	Apr. 20, 1923	Volcanic.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands*—Continued.

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
42	Batangas	Santo Tomas	Tanauan River	U	General Malvar Memorial School.	Pesos.	147007	May 24, 1923	Basaltic sand.
43	Do	Talisay	Talisay beach (Taal Lake).	A	Talisay waterworks.		159123	Sept. 25, 1925	Volcanic tuff.
44	Benguet	Baguio	Engineers hill.		Baguio public-works project.		150866A	Mar. 26, 1924	Chert.
45	Do	do	Government Center		do		150866B	do	Quartz.
46	Do	do	Limestone quarry				123024	Aug. 9, 1916	Limestone-rock screenings.
47	Do	Trinidad					110110A	Nov. 26, 1912	Sand from sedimentary and igneous rocks.
48	Do	do					110110B	Nov. 26, 1925	Altered andesite.
49	Bohol	Batuan	Batuan beach	U	Culverts	12.00	144207	Oct. 19, 1922	Shell and some quartz.
50	Do	Calape	Barrio Sijoton Creek.	A	Calape water reservoir.	3.00	157988	July 16, 1925	Hardened clay.
51	Do	do	Talisay seashore	U	Calape public buildings.	2.50	145445	Jan. 18, 1923	Shell and coral.
52	Do	Colonia	Masing River (inland).	A	Bridges and culverts.	1.00	145401	Jan. 13, 1923	Feldspar.
53	Do	Dauis	Magtubo beach.	U	Dauis Bridge.	0.90	146940	May 19, 1923	Coralline and shells.
54	Do	do	Mana-ol seashore	U	Bohol dispensary pavilion.	3.00	156615	Apr. 21, 1925	Do.
55	Do	do	Umpas Sunculan seashore.	U	do	3.00	156616	do	Do.

56	Do.	Dimiao	Tanguay seashore..	U	Miscellaneous public buildings.	2.00	145398	Jan. 13, 1923	Volcanic.
57	Do.	Duero	Duero seashore ..		Duero public works..		127125	Feb. 19, 1918	Granite, sand and some shells.
58	Do.	do.	do.	U	Bridges and culverts..	2.00	145399	Jan. 13, 1923	Volcanic rock.
59	Do.	Guindulman ..	Guindulman beach	U	Culverts.	1.50	144889	Dec. 4, 1922	Volcanic rock, shell, and quartz.
60	Do.	do.	do.	U	Bridges and culverts..	2.00	145400	Jan. 13, 1923	Decayed serpentine.
61	Do.	Jetafe	Jetafe seashore ..	U	Jetafe municipal building.	1.50	152172A	June 23, 1924	Coralline and quartz.
62	Do.	do.	do.	U	do.	1.50	152172B	do.	Coralline.
63	Do.	Loay	Loay River, 8 kilometers distant.		Loay waterworks..	2.00	125375A	Sept. 19, 1917	Rounded quartz.
64	Do.	do.	Loay River, 14 kilometers distant.		do.		125375B	do.	Rounded coral.
65	Do.	do.	Loay River, 16 kilometers distant.	U	For use as sand blast.	2.50	130482	June 11, 1919	Feldspar, some corals, and shells.
66	Do.	do.	Seashore, kilometer 25.	U	Laboc water reservoir	6.50	157257A	May 28, 1925	Coralline.
67	Do.	do.	do.	U	do.		157257B	do.	Do.
68	Do.	Maribojoc	Seashore at Punta Cruz.	U	Provincial Trade School.	6.00	155542	Feb. 21, 1921	Do.
69	Do.	Palo (Loay)	Seashore at Palo ..	U	Beacon bridges	2.00	145397	Jan. 13, 1923	Angular quartz.
70	Do.	Tagbilaran	Seashore at Davao ..	U	Provincial High School.	2.50	144208A	Oct. 19, 1922	Corals and shells.
71	Do.	do.	Seashore at Davao (Manao).	U	do.	2.50	144208B	do.	Do.
72	Do.	do.	Manao beach near Beacon.	U	do.	2.50	144208C	do.	Do.
73	Do.	do.	Tagbilaran beach ..	U	do.	2.50	144208D	do.	Do.
74	Do.	do.	do.	U	do.	2.00	143950	Sept. 26, 1922	Do.
75	Do.	do.	Beach at mouth of creek.	U	Bohol dispensary pavilion.	7.00	156614	Apr. 21, 1925	Coralline.
76	Do.	Valencia	Valencia beach.	U	Valencia barrio school.	2.50	150416A	Feb. 28, 1924	Do.
77	Do.	do.	Mouth of Panagatan River.	U	do.	2.50	150416B	do.	Do.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands*—Continued.

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
78	Bohol	Valencia	Valencia beach.	U	Valencia barrio school.	Pesos. 2.00	149877	Jan. 24, 1924	Coralline.
79	Bulacan	Angat	Angat River.		Angat River dam.		142811	June 3, 1922	Hard basalt and andesite.
80	Do.	Bocaue		A	Bocaue Bridge.		66785	Mar. 18, 1909	Basalt, magnetite, and quartz.
81	Do.	do.	Bocaue River.				121142A	Oct. 12, 1915	Basaltic and andesitic.
82	Do.	do.	do.	A	Irrigation canal structures.		149420	Dec. 14, 1923	
83	Do.	do.	do.	A	Angat irrigation project.		155434	Feb. 14, 1925	Do.
84	Do.	do.	Bocaue River at bridge.	A	do.		155454A	Feb. 21, 1925	Do.
85	Do.	do.	do.	A	do.		155545B	do.	Do.
86	Do.	do.	do.	A	do.		155545C	do.	Basaltic and andesitic (weathered).
87	Do.	Bustos	Angat River.		do.		142996	June 21, 1922	Hard andesitic.
88	Do.	Calumpit	Bagbag River.		Malolos waterworks.		145288A	Jan. 4, 1923	Basaltic.
89	Do.	do.	Calumpit River.		do.		144857	Dec. 1, 1922	Hard basalt and andesite.
90	Do.	do.	Pullan River.		do.		145288B	Jan. 4, 1923	Basaltic, rounded.
91	Do.	do.	Pullan River at Tibag.		do.		145288C	do.	Basaltic, rounded quartz.
92	Do.	Hagonoy			Hagonoy market.		110032	Nov. 23, 1912	Quartz and magnetite.
93	Do.	do.	Santo Niffo River.				121142B	Oct. 12, 1925	Basaltic and quartz.

94	Do.	Malolos.		Malolos Trade School.	62645	Nov. 25, 1908	Basaltic.
95	Do.	do.		Malolos waterworks.	144856	Dec. 1, 1922	Basaltic and quartz.
96	Do.	Pulilan.	A	Pulilan market.	121142C	Oct. 12, 1915	Basic volcanic.
97	Do.	do.	A	Malolos waterworks.	144591	Nov. 15, 1922	Andesite, hematite, and quartz.
98	Do.	San Ildefonso.		Bureau of Public Works project M211.	110874	Dec. 25, 1912	Vesicular basalt.
99	Do.	Santa Maria.		Santa Maria Bridge.	125491	Oct. 13, 1917	Basalt and andesite.
100	Do.	San Miguel.	U	Bolo Bridge.	113991	Apr. 23, 1913	Basalt and feldspar.
101	Do.	do.	U	San Miguel Bridge.	147908	Aug. 2, 1923	Basalt and andesite.
102	Cagayan.	Aparri.	U	Aparri shore protection.	149619	Jan. 3, 1924	Basalt and andesite.
103	Do.	do.	U	do.	151295	Apr. 23, 1924	Basalt and andesite.
104	Do.	do.	U	do.	150666	Mar. 15, 1924	Basalt and quartz.
105	Do.	do.	A	do.	151833	May 29, 1924	Basalt and andesite.
106	Camaringes Norte.	Paracale.		Paracale waterworks.	158424	Aug. 11, 1925	Quartz.
107	Capiz.	Capiz.	U	Libas Bridge.	121658	Dec. 29, 1915	Quartz, magnetite, olivine, and clay.
108	Do.	Dao.	U	Balucan Bridge.	121656	do.	Basaltic.
109	Do.	Iosan.	U	Iosan School.	121434	Nov. 22, 1915	Quartz, hornblende, tuff, and basalt.
110	Cavite.	General Trias.	U	General Trias School.	151029	Apr. 5, 1924	Vesicular lava and quartz.
111	Do.	Imus.		Indang and Alfonso School.	123445	Nov. 1, 1916	Soft volcanic scoria.
112	Do.	Indang.		do.	122322	Apr. 27, 1916	Vesicular basalt.
113	Do.	Kawit.		Aguinaldo School.	122314A	Apr. 28, 1916	Volcanic tuff and scoria.
114	Do.	do.		do.	122314B	do.	Volcanic.
115	Do.	do.		Calero River Bridge.	123443	Nov. 1, 1916	Do.
116	Do.	do.		Cavite waterworks.	123521	Nov. 15, 1916	Ferromagnesian.
117	Do.	Noveleta.	U	Noveleta River.	149506	Dec. 22, 1923	Basaltic.
118	Do.	do.		San Juan River at bridge.	125977	Jan. 2, 1918	Scoriaceous basalt.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands*—Continued.

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
119	Cavite	Ternate	River bed opposite town.		U. S. Military buildings.	Pesos.	94269	Nov. 17, 1911	Scoria, pumice, and tuff.
120	Cebu	Argao	Argao beach.	A	Concrete culverts.		147975A	Aug. 11, 1923	Coralline.
121	Do.	do.	Argao River.	A	do.		147975B	do.	Basaltic (screenings).
122	Do.	Asturias	Asturias beach.	A	Asturias School building.	3.00	146321	Mar. 31, 1923	Volcanic, quartz, and shells.
123	Do.	Badian	Badian Island.	U	Bridges and culverts.	3.50	145190	Dec. 27, 1922	Corals and shells.
124	Do.	Barili	Japitan beach.	A	Barili School building.	2.40	152599	July 24, 1924	Coralline.
125	Do.	do.	Stream, Barili south road, kilometer 115.8.		Barili south road.		114329	May 8, 1913	
126	Do.	Carcar	Mananga River.	U	Carcar waterworks.	2.40	147129	June 2, 1923	Weathered basalt.
127	Do.	Catmon	Bau River bed.	U	Miscellaneous construction.		145879	Feb. 26, 1923	Angular volcanic.
128	Do.	Cebu	Buhisan River.		Dam, Osmeña waterworks.	1.00	152214	June 26, 1924	Basaltic, andesitic (weathered).
129	Do.	do.	Guadalupe River.	U	Cebu Normal School.	1.60	144671	Nov. 20, 1922	Volcanic scoria.
130	Do.	do.	do.	U	do.	2.20	145880	Feb. 26, 1923	Do.
131	Do.	do.	Mananga River.				78560	May 16, 1910	
132	Do.	do.	do.				123328	Oct. 7, 1916	Derived from sedimentary rocks.
133	Do.	Daan Bantayan.	Town beach.	A	Tank.		143761	Sept. 8, 1922	Corals and shells.
134	Do.	do.	Bogo beach.	A	do.		144247	Oct. 21, 1922	Do.

135	Do.....	Dalaguete Alcoy.	Beach near cemetery.	A	Culverts.....	147399	June 21, 1923	Calcareous.
136	Do.....	Danao.....	Danao River.			78560	May 16, 1910	
137	Do.....	Dumanjug.....	Dumanjug beach.	A	Dumanjug School	144888	Dec. 4, 1922	Corals and shells.
138	Do.....	Liloan.....	Liloan beach.	A	Cebu public works.	146141	Mar. 16, 1923	Hard basalt and quartz.
139	Do.....	Mandawe.....	Mandawe beach.			123327	Oct. 7, 1916	Quartz.
140	Do.....	Opon.....	Butuanon River at Mandawe.	A	Mactan School.	155075	Jan. 15, 1925	Andesitic and basaltic.
141	Do.....	Pinamugahan.....	Pinamugahan beach.	U	Miscellaneous public works.	144970	Dec. 8, 1922	Angular quartz.
142	Do.....	Poron.....	Poron beach.	A	Poron municipal building.	154356	Dec. 4, 1924	Coralline.
143	Do.....	San Remigio.....	San Remigio River.	A	San Remigio municipal building.	139831	Aug. 31, 1921	Corals and shells.
144	Do.....	Santander.....	Beach at mouth of creek.	A	Santander municipal building.	156037	Mar. 19, 1925	Coralline.
145	Do.....	Toledo.....	Tajao River.			122395	May 12, 1916	Basalt, shells, and corals.
146	Ilocos Norte..	Laoag.....	Laoag River bed.		Road and bridges.	121023	Sept. 22, 1915	Andesite, diorite, and quartz.
147	Do.....	.....do.....	Laoag River bank.	A	Laoag Normal School.	149318	Dec. 6, 1923	Andesite and quartz.
148	Do.....	Vintar.....	Vintar River at dam.	A	Laoag-Vintar irrigation project.	150853	Mar. 25, 1924	Weathered andesite and basalt.
149	Do.....	.....do.....	.....do.....	A	.....do.....	151190	Apr. 15, 1924	Andesite, basalt, and quartz.
150	Ilocos Sur....	Candon.....	Santa Cruz River bed.	U	Candon School.	151978	June 10, 1924	Do.
151	Do.....	Vigan.....	Govanter River bed.	U	Provincial Hospital.	151331A	Apr. 25, 1924	Basaltic.
152	Do.....	.....do.....	Govanter River bed (washed).	U	.....do.....	151885	June 3, 1924	Andesitic, basaltic, and quartz.
153	Do.....	.....do.....	Mesitizo River.	U	.....do.....	151331B	Apr. 25, 1924	Basaltic.
154	Iloilo.....	Iloilo.....	Jaro River.	U	Iloilo Normal School.	154417	Dec. 8, 1924	Basaltic, feldspar, and quartz.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands*—Continued.

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter delivered at the job site. <i>Pesos.</i>	Laboratory No.	Date sample was received.	Mineralogic classification.
155	Iloilo	La Paz			Iloilo Provincial Prison		88922	June 14, 1911	
156	Do.	Molo			Molo Bridge		84978	Dec. 9, 1910	
157	Do.	San Miguel	Aganao River		Aganao irrigation project.		142721	May 25, 1922	Andesite, basalt, and quartz.
158	Do.	do.	do.	A	do.		144037	Oct. 3, 1922	Magnetite and quartz.
159	Do.	do.	Oton beach	A	do.		145780	Feb. 17, 1923	Basalt and diorite.
160	Do.	Santa Barbara	Santa Barbara River.	U	Bainica River bridge		155603	Feb. 26, 1925	Basalt, andesite, and limestone.
161	Do.	do.	do.	U	Capiz Elementary School.		159394	Oct. 14, 1925	Andesite and basalt.
162	Laguna	Bay	Bay River		Culverts		145378	Jan. 12, 1923	Do.
163	Do.	Los Baños	Bayog, near lake	A	Miscellaneous buildings.		86085A	Jan. 26, 1911	Do.
164	Do.	do.	Bay River	U	do.		130307	May 22, 1919	Volcanic tuff and scoria.
165	Do.	do.	Los Baños Bay	A			139310	July 18, 1921	
166	Do.	do.	Mayondon No. 1	U	Miscellaneous improvements.		86085B	Jan. 26, 1911	Basalt and shells.
167	Do.	do.	Mayondon No. 2, 100 meters from No. 1.	U	do.		86085C	do.	Do.
168	Do.	Majajay	Majajay River	A	Majajay waterworks		132068	Dec. 6, 1919	Andesite and basalt.
169	Do.	do.	Olla River	U	Majajay market		158671	Aug. 27, 1925	Oxidized argillaceous matter.

170	Do.....	Pagsanjan.....	Pagsanjan River.....			Pagsanjan waterworks.....	128903	Dec. 6, 1918	Angular basaltic sand.
171	Do.....	Rizal.....	Mayton River.....	U		Rizal School.....	143644	Aug. 29, 1922	Scoriaceous basalt.
172	Do.....	do.....	do.....	U		do.....	145733	Feb. 14, 1923	Do.
173	Do.....	Santa Cruz.....	Malunod River.....			Bañadero River Bridge.....	142380	Apr. 20, 1922	Weathered basaltic sand.
174	Do.....	do.....	Santa Cruz River.....	A		Santa Cruz Hospital.....	149829	Jan. 21, 1924	Basaltic and andesitic.
175	Do.....	San Pablo.....	Bañadero River.....	A		Bañadero River Bridge.....	142608	May 12, 1922	Andesitic dioritic.
176	Do.....	do.....	Lucena beach.....			do.....	142926	June 16, 1922	Do.
177	Leyte.....	Alangalang.....	Dapdap River.....			Provincial public works.....	147651A	July 11, 1923	Basaltic and magnetite.
178	Do.....	do.....	Lingayon River.....			do.....	147651B	do.....	Weathered basaltic sand.
179	Do.....	Barugo.....	Tunga River.....			do.....	147651C	do.....	Do.
180	Do.....	do.....	Barugo beach.....			Barugo School.....	121025	Sept. 22, 1915	Basaltic.
181	Do.....	Bato.....	Bato beach.....				120782	Aug. 12, 1915	Quartz, ferromagnesian, and shells.
182	Do.....	Burauen.....	Burauen River.....			Provincial public works.....	147651D	July 11, 1923	Basalt and quartz.
183	Do.....	Carigara.....	Carigara River.....	U		Carigara School.....	145326	Jan. 8, 1923	Volcanic.
184	Do.....	Dagami.....	Guinarona River.....			Provincial public works.....	147651E	July 11, 1923	Fairly hard basaltic.
185	Do.....	Dulag.....	Tibuc River.....			do.....	147651F	do.....	Weathered basalt.
186	Do.....	Magellan.....	Triana beach.....	U		Limasawa School.....	149986	Feb. 1, 1924	Coralline.
187	Do.....	Ormoc.....	Anilao River.....	U		Ormoc market.....	159886	Nov. 11, 1925	Basalt and andesite.
188	Do.....	Palo.....	Mallirong River.....			Provincial public works.....	147651G	July 11, 1923	Basaltic (weathered).
189	Do.....	Pastrana.....	Calogcoog River.....			do.....	147651H	do.....	Coarse basalt.
190	Do.....	Tabontabon.....				Tabontabon School.....	121416	Nov. 24, 1915	Magnetite, quartz, and pyroxene.
191	Do.....	Tacloban.....	Beach, kilometer 4, Tacloban-Carigara road.			Tacloban wharf.....	150161A	Feb. 12, 1924	Andesite, a little quartz, and shells.
192	Do.....	do.....	Beach, kilometer 5, Tacloban-Carigara road.	U		For use as sand blast.....	130434	June 12, 1919	Andesite and trachyte.
193	Do.....	do.....	Camp Bampuo.....	U		Tacloban wharf.....	146284A	Mar. 27, 1923	Quartz, corals, and shells.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands*—Continued.

Trac- ing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the con- struction of—	Esti- mated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classi- fication.
194	Leyte	Tacloban.	Daguitan River.	U	For use as sand blast.	<i>Pesos.</i> 2.50	130433	June 11, 1919	Andesite, some feld- spar, and quartz.
195	Do.	do.	Kilometer 4.	U	Tacloban wharf.	0.75	146284B	Mar. 27, 1923	Quartz, corals, and shells.
196	Do.	do.	Sabang beach.	U	do.	0.75	146284C	do.	Do.
197	Do.	do.	do.	U	do.	2.00	150161B	Feb. 12, 1924	Fine andesite and quartz.
198	Do.	do.	Tigbao River		Tacloban port works.	0.80	121583	Dec. 15, 1915	Quartz, sandstone, and andesite.
199	Do.	Tanauan.	Malaguicay River.		Provincial public works.		147651I	July 11, 1923	Basalt and magnetite.
200	Marinduque	Boac.	Boac seashore	U	Boac pier construction.	1.20	155971	Mar. 17, 1925	Andesite, basalt, and quartz.
201	Do.	Gasan.	Gasan beach.		Gasan-Buenavista road.		119706	Jan. 25, 1915	Weathered basalt.
202	Do.	do.	Matandang Asan River.	U	Matandang Asan Bridge.	0.50	151128A	Apr. 11, 1924	Andesite and quartz.
203	Do.	do.	Gasan beach.	U	do.	0.50	151128B	do.	Andesite and quartz.
204	Do.	do.	Tiguian River.		Gasan-Buenavista road.		119706	Jan. 25, 1915	Andesite and diorite.
205	Masbate.	Masbate.	Baleno seashore	A	Masbate market.	5.00	153778	Oct. 23, 1924	Andesite and basalt.
206	Do.	do.	Togbo River	A	do.	5.00	152783	Aug. 7, 1924	Andesite and basalt
207	Do.	Milagros.	Asid River.	U	Milagros School.	5.00	149618	Dec. 26, 1923	Andesite and basalt (weathered).
208	Do.	do.	Lumbang River.	U	do.	7.00	149505	Dec. 22, 1923	Do.
209	Mindanao	Cagayan (Misa- mis).	Cagayan River.		Cagayan wharf.		122045A	Mar. 10, 1916	Basalt and quartz.

210	Do	do	Cagayan beach		do	122045B	do	Basalt, quartz, and shells.
211	Do	do	Cagayan River		Cagayan Central School.	123101	Aug. 24, 1916	Do.
212	Do	do	Iponan River		Iponan and Molugan School.	141781	Feb. 20, 1922	Weathered andesite, quartz, and feldspar.
213	Do	do	Mouth of Cugman River.		Macabalan wharf.	122187	Apr. 10, 1916	Magnetite, olivine, and quartz.
214	Do	Cotabato (Cotabato).	Cotabato River	U	Cotabato Hospital tank.	148647	Oct. 9, 1923	Tuff, pumice, and cinders.
215	Do	do	Rio Grande	U	do	147911	Aug. 2, 1923	Limestone-rock screenings.
216	Do	do	Linuac beach		do	121499	Nov. 30, 1915	Quartz and shells.
217	Do	do	do		do	124391	Apr. 17, 1917	Corals, shells, and quartz.
218	Do	Davao (Davao)	Davao River, 2.5 kilometers distant.	U	Davao wharf.	157985	July 16, 1925	Basalt and andesite.
219	Do	do	Davao River, 3.5 kilometers distant.	U	do	157986	do	Do.
220	Do	Jolo (Sulu)	Baliwasan beach (Zamboanga).	U	Miscellaneous works.	118287	Feb. 21, 1914	Corals and shells.
221	Do	do	do		Jolo wharf.	148237A	Sept. 3, 1923	Basalt and coralline.
222	Do	do	do	U	do	148237B	do	Do.
223	Do	do	Caldera Bay	U	do	148237C	do	Basalt and quartz.
224	Do	do	Tumaga River (Zamboanga).	U	do	148237D	do	Do.
225	Do	do	Maimbung River		Culverts.	125574	Nov. 1, 1917	Volcanic sand and quartz.
226	Do	Surigao (Surigao)	Surigao beach		High School building.	152656	July 29, 1924	Basalt and andesite.
227	Do	Zamboanga (Zamboanga)	Baliwasan beach	U	Zamboanga wharf extension.	156546A	Apr. 16, 1925	Basalt, andesite, and corals.
228	Do	do	do	U	do	156546B	do	Do.

^b Tested at the age of 18 days and 30 days, respectively.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands*—Continued.

Tac- ing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the con- struction of—	Esti- mated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classi- fication.
229	Mindanao	Zamboanga (Zamboanga).	Tumaga River (Zamboanga).		Zamboanga waterworks.	Pesos.	122303A	Apr. 26, 1916	Basalt, andesite, and quartz.
230	Do.	do.	do.		do.		122303B	do.	Do.
231	Do.	do.	Zamboanga beach.	U	Jolo wharf.	1.50	147515	July 2, 1923	Basaltic.
232	Do.	do.	do.	U	do.	2.00	154786	Jan. 6, 1925	Basalt and corals.
233	Do.	do.	do.		Zamboanga Normal	2.00	127040	Feb. 6, 1918	Decayed metaphor- mic.
234	Do.	do.	do.		do.	0.90	127041	do.	Hard basalt and co- rals.
235	Nueva Ecija.	Carangian.	Carangian River.	U	Kabolinawan Bridge.	1.50	147350	June 19, 1923	Basalt and andesite.
236	Do.	Cabanatuan.	Rio Grande.	U	Provincial Hospital.	2.00	150669	Mar. 15, 1924	Basalt and feldspar.
237	Occidental Negros.	Bacolod.	Lupit River.	U	Bacolod Provincial Hospital.	3.00	149510	Dec. 22, 1923	Basalt and feldspar.
238	Do.	do.	do.	U	do.	2.50	156703	Apr. 27, 1925	Andesite and feldspar.
239	Do.	Bago.	Bago River.	U	Bago School extension.	2.00	151982	June 10, 1924	Basalt, andesite, and quartz.
240	Do.	Binalbagan.	Binalbagan River.	U	Binalbagan School.	2.00	149507	Dec. 22, 1923	Basalt.
241	Do.	Cadiz.	Talabean River.		Cadiz municipal market	5.00	158885	Sept. 10, 1925	Weathered argilla- ceous.
242	Do.	Himamaylan.	Talabaan-Diot River.	U	Himamaylan School.	4.00	150855	Mar. 25, 1924	Andesite and basalt weathered.
243	Do.	Isabela.	Binalbagan River.	U	Isabela School.	3.50	153663	Oct. 16, 1924	Do.
244	Do.	do.	Guintubhan River.	U	do.	3.50	154169	Dec. 21, 1924	Andesitic porphyry.
245	Do.	La Carlota.	Alejandro River.	U	La Carlota School.	2.00	148964	Nov. 3, 1923	Basalt.

246	Do.....	La Castellana.....	Bungahin River.....	La Castellana municipal building.....	2.50	158983	Sept. 17, 1925	Basalt and hornblende.
247	Do.....	do.....	do.....	do.....	2.00	159768	Nov. 3, 1925	Basic igneous.
248	Do.....	Mao.....	Maragandang River.....	Mao School.....	3.00	150748	Mar. 19, 1924	Andesite and quartz.
249	Do.....	Pulupandan.....	Bago River.....	Pulupandan wharf.....		158271	July 31, 1925	Andesite and basalt, weathered.
250	Do.....	Talisay.....	Matabang River.....	Talisay School.....	2.00	151004	Apr. 3, 1924	Andesite and quartz.
251	Oriental Negros.....	Bais.....	Bais River.....	Bais River Bridge.....		122046	Mar. 10, 1916	Coralline and quartz.
252	Do.....	Dumaguete.....	Banica River.....	Storage tank.....	2.40	145642A	Feb. 5, 1923	Granitic sand and quartz.
253	Do.....	do.....	Ocoy River.....	do.....	6.00	145642B	do.....	Do.
254	Palawan.....	Coron.....	Banga River.....	Coron wharf.....	4.00	155109	Jan. 23, 1925	Feldspar, very much weathered.
255	Do.....	do.....	Beach near wharf.....	do.....		157987	July 16, 1925	Feldspar.
256	Do.....	do.....	Coron beach.....	do.....		124014	Feb. 6, 1917	Iron-stained quartz.
257	Pampanga.....	Angeles.....	Abacan River.....	Angeles Bridge No. 89.....	3.00	146673	Apr. 25, 1923	Angular glassy feldspar.
258	Do.....	do.....	do.....	do.....		147419	June 22, 1923	Andesite.
259	Do.....	Floridablanca.....	Valdez River.....	Floridablanca market.....		159229	Oct. 2, 1925	Limestone and quartz.
260	Do.....	do.....	do.....	do.....		159887	Nov. 11, 1925	Feldspar and quartz.
261	Do.....	Magalang.....	Quintangil River.....	Magalang municipal building.....	2.50	146671	Apr. 25, 1923	Basalt and quartz.
262	Do.....	Mexico.....	Barrio San Agustin.....	Santa Ana School.....		149486A	Dec. 20, 1923	Andesite and quartz.
263	Do.....	do.....	Barrio Santo Rosario.....	do.....		149486B	do.....	Do.
264	Pangasinan.....	Aguilar.....	Aguilar River.....	Aguilar School.....	1.75	146985	May 22, 1923	Diorite.
265	Do.....	Alcala.....	Barrio San Juan.....	Alcala School.....	3.50	144572	Nov. 14, 1922	Basalt and feldspar.
266	Do.....	Anda.....	Balincaguin River.....	Anda School.....	5.00	146986	May 22, 1923	Ferromagnesian and feldspar.
267	Do.....	Balungao.....	Villasis River.....	Balungao School.....	4.00	146157	Mar. 17, 1923	Basic volcanic and feldspar.
268	Do.....	Bautista.....	Agno River.....	Bayambang School.....	3.70	147318	July 25, 1923	Basalt, andesite, and feldspar.
269	Do.....	Bani.....	Agno River at Labrador.....	Bani School.....	5.00	145627	Feb. 3, 1923	Angular feldspar.

TABLE 8.—Granulometric composition and tensile and compressive strengths of Philippine sands—Continued.

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available; A, abundant; L, limited; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
270	Pangasinan.	Bolinao.	Pilubnan River.	U	Bolinao School.	Pesos.			
271	Do.	Tambacan.	Tambacan.	U	Burgos Central School.	5.00	152865	Aug. 14, 1924	Coralline limestone.
272	Do.	Calasiao.	Abeloleng River at San Jacinto.	U	Calasiao Central School.	4.00	145188	Dec. 27, 1922	Volcanic rock.
273	Do.	do.	Calasiao-Malabago River.	U	Provincial Hospital.	4.00	144639	Nov. 17, 1922	Basalt and feldspar.
274	Do.	do.	Malabago River.	U	Calasiao School.	3.50	153589	Oct. 11, 1924	Do.
275	Do.	do.	Mariquita River.	U	do.	2.60	144200	Oct. 18, 1922	Feldspar.
276	Do.	do.	Santa Barbara River.	U	do.	4.00	145277	Jan. 4, 1923	Do.
277	Do.	do.	Tarlac River.	U	do.	3.00	145189	Dec. 27, 1922	Feldspar and quartz.
278	Do.	Dagupan.	San Jacinto-Canoa River.	U	Provincial Hospital.	2.00	145099	Dec. 19, 1922	Glassy feldspar.
279	Do.	Lingayen.	Labrador River.	U	Lingayen High School.	4.00	152549	July 22, 1924	Basalt and andesite.
280	Do.	Malasiqui.	Malasiqui River.	U	Malasiqui School.	3.50	149973	Jan. 31, 1924	Do.
281	Do.	do.	do.	U	do.	2.00	146044	Mar. 10, 1923	Ferromagnesian and quartz.
282	Do.	Manaoag.	Asingan River.	U	Manaoag School building.	2.40	146427	Apr. 10, 1923	Andesitic.
283	Do.	Santa Barbara.	Santa Barbara River.	U	Provincial Hospital.	2.20	152247	June 30, 1924	Weathered grains, basalt, and andesite.
284	Do.	San Carlos.	Ano Nilintap (Malasiqui).	U	San Juan Bridge.	4.50	153605	Oct. 13, 1924	Andesite and feldspar.
285	Do.	do.	Abeloleng River.	U	San Carlos School.	2.80	149821	Jan. 21, 1924	Basalt, feldspar, and shells.
286	Do.	do.	Bogtong River.	U	San Juan Bridge.		144407	Nov. 3, 1922	Basalt and quartz.
						2.30	150493	Mar. 5, 1924	Basalt, andesite, and shells.

287	Do.....	Malabago River.....	U	San Carlos School building.....	143742	July 7, 1922	Feldspar and andesite.
288	Do.....	River bank at San Fabian.....	A	do.....	143265	July 19, 1922	Volcanic and felspar.
289	Do.....	San Jacinto.....	A	San Jacinto School building.....	145345	Jan. 9, 1923	Do.
290	Do.....	do.....	A	do.....	145666	Feb. 7, 1923	Andesite angular.
291	Do.....	Tayug.....	A	Tayug School.....	144072	Oct. 6, 1922	Andesite and felspar.
292	Do.....	Las Piñas.....		Las Piñas Bridge.....	80997	Aug. 16, 1910	Vesicular lava.
293	Do.....	Mariquina.....	A	Angona Bridge.....	121816	Jan. 27, 1916	Basalt, magnetite, and quartz.
294	Do.....	do.....	U	Zamboanga water-works.....	122021	Mar. 7, 1916	Andesite, basalt, and quartz.
295	Do.....	do.....	U	Pier No. 7, Manila.....	158001	July 17, 1925	Andesite and basalt.
296	Do.....	do.....	U	do.....	158318A	Aug. 4, 1925	Do.
297	Do.....	do.....	U	do.....	158318B	do.....	Do.
298	Do.....	McKinley.....	U	Legislative Building, Manila.....	151600A	May 14, 1924	Do.
299	Do.....	do.....	U	do.....	151600B	do.....	Do.
300	Do.....	do.....	U	Jones Bridge subway.....	151984	June 10, 1924	Do.
301	Do.....	do.....	U	Legislative Building, Manila.....	152145	June 20, 1924	Do.
302	Do.....	Novaliches.....		Novaliches Bridge.....	65401	Feb. 24, 1909	
303	Do.....	Pasig River.....	A	Fort McKinley.....	94269	Nov. 17, 1911	Basalt and shells.
304	Do.....	do.....	U	Legislative Building, Manila.....	130366	May 26, 1919	Basalt and andesite.
305	Do.....	do.....	U	San Luis municipal building, Batangas.....	146939	May 19, 1923	Andesite, diorite, and quartz.
306	Do.....	do.....	U	Indang waterworks, Cavite.....	147303	June 16, 1923	Basalt.
307	Do.....	do.....	U	University of the Philippines chemical laboratory.....	149466	Dec. 18, 1923	Basalt and andesite.
308	Do.....	do.....	U	Legislative Building, Manila.....	145643A	Feb. 5, 1923	Andesite.

TABLE 8.—Granulometric composition and tensile and compressive strengths of Philippine sands—Continued.

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; L, limited; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter delivered at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
309	Rizal	Pasig	Pasig River	U	Legislative Building, Manila.	Pesos. 2.40	145643B	Feb. 5, 1923	Andesite.
310	Do.	do.	do.	U	do.	2.40	145643C	do.	Do.
311	Do.	do.	do.	U	do.	2.40	145643D	do.	Do.
312	Do.	do.	do.	U	Pasay concrete road	3.50	149666	Jan. 8, 1924	Basalt and andesite.
313	Do.	do.	do.	U	do.	4.00	149777	Jan. 17, 1924	Basalt and diorite.
314	Do.	do.	Pasig River (Bambang).	U	Jones Bridge, Manila.	2.40	152173	June 23, 1924	Basalt and andesite.
315	Do.	do.	Pasig River	U	Legislative Building, Manila.	2.50	154012	Nov. 11, 1924	Do.
316	Do.	do.	do.	U	Philippine General Hospital.	3.20	153845	Oct. 29, 1923	Basalt and andesite.
317	Romblon	Romblon.	Seashore	U	Romblon concrete pier.	3.00	144383	Nov. 1, 1922	Coralline.
318	Do.	do.	do.	U	do.	3.00	144776	Nov. 25, 1922	Corals and shells.
319	Do.	do.	do.	U	do.	3.00	144777	do.	Coralline.
320	Do.	do.	Beach at Sitio Bantayan.	U	Romblon radio tower		138831	June 11, 1921	Do.
321	Samar	Borongan	Bato River at Canabong.		Borongan Bridge		151148A	Apr. 12, 1924	Andesite and basalt.
322	Do.	do.	Borongan River at Sulop.		do.		151148B	do.	Weathered andesite and basalt.
323	Do.	do.	Canabon beach		do.		151148C	do.	Andesite and basalt.
324	Do.	do.	Mayhaligue River	U	do.		150108A	Feb. 8, 1924	Very much weathered basalt.

325	Do.....	do.....	Sabang River.....	U	do.....	150108B	.....do.....	Slightly weathered basalt.
326	Do.....	do.....	Sorbas beach.....		do.....	151148D	Apr. 12, 1924	Andesite and basalt.
327	Do.....	do.....	Sunco beach near Sabang.		do.....	151148E	.....do.....	Do.
328	Do.....	Calbayog.....	Calbayog beach.		Calbayog north and south bridges.	118232A	Feb. 12, 1924	Andesite.
329	Do.....	do.....	do.....		do.....	119453	Nov. 16, 1924	Do.
330	Do.....	do.....	Calbayog beach (pit).		do.....	118232B	Feb. 12, 1924	Sandstone, shale, and quartz.
331	Do.....	do.....	Malapalo Tinambacan.		Calbayog municipal building.	154091	Nov. 14, 1924	Andesite and feldspar.
332	Do.....	do.....	Tagdaranao beach.	U	do.....	154357	Dec. 4, 1924	Andesite.
333	Do.....	Cataman.....	Seashore.....	U	Cataman market.....	151088	Apr. 9, 1924	Quartz.
334	Do.....	Catbalogan.....	Near water reservoir.	U	Catbalogan waterworks.....	145565	Jan. 27, 1923	Volcanic and quartz.
335	Do.....	Llorente.....	River at Sinacan.		Llorente School building.	152714	Aug. 2, 1924	Andesite and basalt.
336	Do.....	do.....	Llorente beach.....		do.....	152715	.....do.....	Do.
337	Do.....	do.....	Llorente River at Lubuagan.		do.....	152730	.....do.....	Do.
338	Sorsogon.....	Bulan.....	San Ramon River.....	U	Bulan market.....	160425	Dec. 23, 1925	Basalt and andesite.
339	Do.....	Castilla.....	Yawa River (Daraga)	U	Kinadkad Bridge.....	159122	Sept. 25, 1925	Volcanic.
340	Do.....	do.....	do.....	U	do.....	159767	Nov. 3, 1925	Do.
341	Do.....	Donsol.....	Donsol River.....	U	Donsol market.....	147547	July 5, 1923	Basalt.
342	Do.....	Gubat.....	Artiman River.....	U	Sagurong Bridge.....	150908	Mar. 28, 1924	Weathered andesite and quartz.
343	Do.....	do.....	Sagurong River.....	U	do.....	150246	Feb. 16, 1924	Weathered basalt.
344	Do.....	Juban.....	Juban River.....	U	Juban School.....	150556	Mar. 28, 1924	Weathered andesite.
345	Do.....	do.....	Talinga River.....	U	do.....	151089	Apr. 9, 1924	Andesite and quartz.
346	Do.....	Sorsogon.....	Lantic River.....		Sorsogon waterworks.....	154358	Dec. 4, 1924	Andesite and weathered diorite.
347	Do.....	do.....	Sorsogon.....	A	do.....	153779	Oct. 23, 1924	Volcanic.
348	Do.....	do.....	do.....	A	Provincial Hospital.....	160254	Dec. 10, 1925	Diorite, angular.
349	Surigao.....	Bilangbilang.....	Surigao River.....	A	Bilangbilang wharf.....	121266	Oct. 26, 1915	Limestone and quartz.

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350	Surigao.	Bilangbilang.	Surigao River at wharf.	A	Bilangbilang wharf.	---	121257	Oct. 25, 1915	Quartz, basalt, and andesite.
351	Tarlac.	Camiling.	Camiling River.		Camiling market.	---	117776	Oct. 30, 1913	Feldspar, ferromagnesian.
352	Do.	Capaz.	Santiago River.		Capaz-Concepcion road.	---	123447	Nov. 1, 1916	Feldspar.
353	Do.	O'Donnell.	O'Donnell River.		O'Donnell irrigation works.	---	84560A	Nov. 22, 1910	Feldspar, pumice, and quartz.
354	Do.	do.	do.		do.	---	84560B	do.	Do.
355	Do.	Paniqui.	Tarlac River.		Paniqui School building.	---	157694	June 27, 1925	Feldspar and quartz.
356	Do.	San Miguel.	Cutcut River.		O'Donnell irrigation works.	---	158312	Aug. 4, 1925	Granitic and quartz.
357	Do.	do.	O'Donnell River.	U	do.	---	160177	Dec. 3, 1925	Quartz and feldspar.
358	Do.	Tarlac.	Tarlac River.	U	do.	---	75663	Jan. 6, 1910	Andesite, feldspar, and hornblende.
359	Do.	do.	Tarlac.	U	do.	---	75663	do.	Do.
360	Tayabas.	Candelaria.	Candelaria-Tiaong, 18.2 kilometers.		Lucena-Tiaong road.	---	125876	Dec. 8, 1917	Angular volcanic.
361	Do.	do.	Cuyapo River.	A	Candelaria water-works.	2.50	156807	May 4, 1925	Andesite and diorite.
362	Do.	Infanta.	Agos River.	A	Infanta municipal building.	2.50	158970	Sept. 16, 1925	Diorite.
363	Do.	do.	Lamigan River.	A	do.	3.50	158975	Aug. 7, 1925	Weathered andesite.

364	Do.	Lopez.	Siain beach.	A	Lopez municipal building.	160352	Dec. 18, 1925	Andesite, limestone, and quartz.
365	Do.	Lucena.	Dumacaa River.	A	Hospital building.	149688	Jan. 10, 1924	Andesite.
366	Do.	Sariaya.	Munting River, Pit No. 1.		Lucena-Tiaong road.	125700	Nov. 22, 1917	Basalt.
367	Do.	Siain.	Siain beach.	A		159068	Sept. 22, 1925	Quartz, limestone, and shells.
368	Do.	Tayabas.	Alitao River.	A	Tayabas market.	152450	July 12, 1924	Weathered basalt and andesite.
369	Do.	Tiaong.	300 meters from bridge.		Lagnas River Bridge	142927	June 16, 1922	Scoriaceous basalt and quartz.
370	Do.	do.	Just below bridge.	U	do.	143315	July 24, 1922	Weathered basalt.
371	Do.	do.	Mainit River.	U	Tiaong waterworks.	156808	May 4, 1925	Weathered andesite.
372	Do.	Unisan.	Banks of Kalylayan River.	U	Kalylayan Bridge.	154615	Dec. 20, 1924	Quartz and diorite.
373	Zambales.	Alhambra.	Mouth of Lucapon River.	U	Lucapon Bridge.	123119	Aug. 28, 1916	Volcanic quartz and shells.
374	Do.	Cabangan.	Anunang River.	U	Anunang Bridge.	121917	Feb. 16, 1925	Weathered andesite and quartz.
375	Do.	do.	Mouth of Cauayan River.	U	Iba-Subic Road Bridge.	121641	Dec. 23, 1925	Feldspar.
376	Do.	do.	Kauayan-Kiling River.	U	do.	121640	do.	Andesite, basalt, and feldspar.
377	Do.	do.	Lauis River.	U	Yamot River Bridge.	122530	June 5, 1916	Andesite and feldspar.
378	Do.	do.	Yamot River.	U	do.	122531	do.	Feldspar, some olive, and pyroxene.
379	Do.	Candelaria.	Sitio Galagala.	U	Candelaria School building.	123118	Aug. 28, 1916	Volcanic and feldspar.
380	Do.	Santa Cruz.	Bayto River.	U	Santa Cruz School.	146669	Apr. 25, 1923	Basalt.
381	Do.	do.	Perpetuo River.	U	do.	145824	Feb. 21, 1923	Ferromagnesian.
382	Do.	San Marcelino.	Santo Tomas River at Santa Fé.	U	Santo Tomas irrigation works.	153274	Sept. 16, 1924	Feldspar and quartz.

TABLE 8.—*Granulometric composition and tensile and compressive strengths of Philippine sands*—Continued.

Tracing No.	Granulometric analysis. Per cent particles passing through screens.										Three-screen analysis. Per cent particles.			Specific gravity.	Percentage of voids.	Uniformity coefficient.	Tensile strength in pounds per square inch (1:3 mortar).				Compressive strength in pounds per square inch (1:3 mortar).				Strength at the age of 28 days.	
																	Sard specimens.				Standard sand.				Specimen standard $\times 100$.	
	10	20	30	40	50	60	80	100	200	Coarse.	Me- dium.	Fine.														
1	88	66	41	27	19	13	6	4	—	23	58	19	2.72	40.1	3.1	217	246	267	324	1460	2010	1864	2610	76.1	77.1	
2	93	66	38	22	13	7	4	3	1	20	67	13	2.75	37.1	3.2	250	304	227	347	1930	3410	1910	3380	87.6	100.9	
3	85	55	27	17	10	3	1	0.7	—	33	57	10	2.69	42.1	2.8	246	352	354	402	1375	2600	1611	2472	87.3	105.2	
4	85	52	26	12	7	4	3	2	1	34	59	7	2.72	41.2	2.4	206	317	284	403	1877	3283	2119	2780	104.5	118.2	
5	71	48	29	17	12	7	3	2	1	40	48	12	2.85	41.5	3.5	211	328	284	403	1533	2890	2119	2780	81.4	104.2	
6	87	62	38	21	12	6	3	2	1	26	62	12	2.61	40.9	2.6	165	233	243	361	1361	2115	1878	2468	64.5	85.6	
7	91	41	25	16	9	7	4	3	2	40	51	9	2.58	31.3	3.3	196	234	255	365	1659	2593	1923	2777	63.9	93.5	
8	79	53	35	22	16	10	5	2	—	38	46	16	2.80	37.1	4.2	250	380	270	362	1550	2537	1925	2737	105.0	93.1	
9	96	68	34	25	19	14	10	5	—	21	60	19	2.73	33.1	3.6	275	280	316	390	2415	2955	2550	2906	71.8	101.5	
10	82	53	40	34	27	23	12	9	—	38	35	27	2.66	27.1	6.1	291	348	317	333	2528	3500	2182	3182	104.1	110.1	
11	98	25	3	—	—	—	—	—	—	52	48	0	2.70	36.1	2.1	258	380	236	349	1470	2920	1330	2994	109.1	97.6	
12	86	10	2	—	—	—	—	—	—	72	28	0	2.70	35.1	1.8	271	409	236	349	1540	2994	1330	2994	117.1	100	
13	94	57	33	16	9	4	2	1	—	30	61	9	2.61	33.2	2.5	163	327	241	339	904	2197	1704	2328	96.5	94.4	
14	94	44	15	5	3	2	—	—	—	36	61	3	2.62	35.1	2.1	210	322	241	339	1330	2884	1704	2328	95.1	124.1	
15	100	97	93	77	54	28	14	8	2	—	—	—	2.97	39.7	1.6	145	229	241	346	998	1179	2148	3108	66.2	37.9	
16	92	74	52	33	17	9	4	3	2	16	67	17	2.62	36.7	2.3	119	235	222	340	799	1525	2100	3230	69.1	47.3	
17	82	48	24	12	7	4	3	2	—	37	56	7	2.65	36.1	2.7	206	316	220	313	1410	2695	1575	2618	99.1	103.1	
18	88	62	42	27	12	7	2	1	—	26	62	12	2.62	44.1	2.6	175	303	220	313	1048	2039	1424	2994	97.1	68.1	
19	74	32	22	5	3	2	—	—	—	46	51	3	2.80	36.2	2.3	290	356	241	339	1476	2921	1704	2328	105.1	125.8	
20	96	76	37	16	9	3	2	—	—	16	75	9	2.65	35.9	1.9	157	260	241	339	935	1843	1704	2328	76.7	79.1	
21	88	63	43	32	25	16	8	5	—	27	48	25	2.73	43.1	3.7	269	307	315	402	2440	3473	2175	3203	76.4	77.1	
22	92	53	17	4	3	2	2	2	1	22	75	3	2.70	42.1	2.1	286	395	286	403	1560	2720	2100	2722	98.1	99.8	
23	100	98	88	78	56	38	18	9	—	1	43	56	2.75	50.1	1.9	141	249	277	366	673	948	—	—	68.1	—	

24	95	74	36	21	8	3	2	1	1	29	63	8	2.55	2.1	*312	*340	*4587	*4288	91.8	107.1					
25	98	80	40	21	9	7	5	3	2	11	80	9	2.67	38.1	180	262	251	1608	2612	70.8	71.2				
26	89	57	33	18	9	7	5	3	2	32	59	9	2.68	38.6	2.5	202	261	280	1737	2477	70.5	111.1			
27	92	74	52	37	23	13	7	4	2	19	58	23	2.93	37.2	3.1	262	284	281	1397	2595	80.7	124.1			
28	84	60	37	27	20	12	8	7	5	27	53	20	2.82	29.3	4.1	241	246	281	1897	2595	70.0	99.1			
29	94	48	17	9	7	4	3	2	1	31	62	7	2.67	38.5	2.4	219	344	281	1897	2595	97.9	91.5			
30	98	92	73	51	30	20	12	7	3	4	66	30	2.75	40.1	2.3	107	220	282	333	889	1737	1714	2318	66.1	75.1
31	83	48	23	9	5	3	2	1	1	33	62	5	2.66	35.5	2.3	213	331	282	333	1678	2903	1714	2318	99.5	125.6
32	78	44	21	12	8	4	3	2	1	40	52	8	2.61	34.2	3.1	209	328	282	333	1698	2283	1714	2318	98.5	98.5
33	74	33	14	8	4	3	2	1	1	46	50	4	2.26	41.6	2.7	210	300	304	410	1510	2342	1950	2830	73.2	82.9
34	88	57	28	12	6	3	2	2	1	28	66	6	2.31	41.1	2.3	160	239	290	403	1111	1376	2130	2722	59.3	50.5
35	97	67	25	8	4	2	1	1	1	14	82	4	2.30	39.1	2.1	128	220	244	350	653	1337	1803	2397	62.8	55.8
36	98	74	53	32	17	7	3	2	1	16	67	17	2.52	42.1	3.1	164	242	304	410	995	1845	1950	2830	59.1	65.2
37	57	26	12	6	4	3	2	1	1	62	34	4	2.24	37.1	3.2	208	284	268	387	1194	2059	1596	2279	73.3	90.4
38	93	77	54	37	26	14	8	6	2	14	60	26	2.55	39.8	3.1	206	305	246	335	1340	2236	2102	2712	91.1	82.5
39	61	28	15	8	5	3	2	1	1	60	35	5	2.32	46.4	3.1	173	265	269	394	906	1693	1668	2708	67.3	62.5
40	99	76	43	24	16	9	6	4	2	8	76	16	2.66	51.1	2.7	152	214	251	370	773	1583	1811	2762	57.8	57.2
41	100	96	87	75	56	30	15	8	2	4	40	56	2.75	44.2	2.1	137	207	252	351	943	1709	1913	3045	57.4	56.1
42	94	50	26	17	11	8	5	4	2	28	61	11	2.43	41.1	2.9	169	257	276	341	1118	2309	1948	2609	75.3	88.5
43	97	72	37	27	7	3	2	1	1	11	82	7	2.81	41.1	2.1	198	306	255	390	1235	2320	1756	2688	78.5	86.9
44	48	23	13	8	6	4	3	3	3	14	80	6	2.55	38.4	4.6	331	456	240	326	1990	3500	1732	2121	140.1	164.6
45	91	83	77	74	70	66	63	58	30	15	15	70	2.66	49.6	4.1	131	189	240	326	611	1110	1732	2121	58.1	52.2
46	74	43	24	17	12	8	6	4	2	45	43	12	2.60	39.6	4.5	400	452	259	336	1209	2783	1027	1576	134.6	108.1
47	99	94	79	69	42	25	14	6	2	4	54	42	2.85	44.5	2.1	148	220	266	343	1209	2783	1027	1576	134.6	108.1
48	70	44	33	23	20	17	15	12	1	47	83	20	2.54	44.8	8.4	395	504	266	343	1209	2783	1027	1576	134.6	108.1
49	97	86	79	60	32	17	15	12	1	21	79	2	2.67	39.8	2.4	132	168	276	332	1672	2078	2145	3499	50.6	59.4
50	70	35	17	9	7	4	3	2	2	49	44	7	2.29	45.8	3.1	164	220	310	432	657	996	2631	3428	50.8	29.6
51	97	77	59	47	38	26	17	12	3	16	46	38	2.69	39.4	3.2	235	270	319	371	1722	2393	2394	3394	72.8	70.5
52	97	81	53	32	20	12	7	3	2	8	72	20	2.56	43.4	2.1	153	239	273	388	1350	2093	2559	2969	61.6	70.7
53	98	88	65	43	28	16	10	7	3	6	66	28	2.65	31.1	2.7	186	255	254	319	821	1413	1810	2155	80.1	65.6
54	98	95	86	71	46	14	4	2	1	4	50	46	2.77	46.1	1.5	123	225	285	373	660	864	1881	2310	82.3	37.4
55	47	8	3	7	7	7	7	7	7	53	47	7	2.67	48.9	2.5	253	353	289	392	1805	2648	1886	2730	90.1	96.8
56	97	83	47	13	7	3	2	2	2	10	83	7	2.62	37.8	1.5	256	322	273	388	1794	3088	2559	2969	83.1	104.1

• Proportion of mortar mixture by weight 1 : 2.

* Proportion of mortar mixture by weight 1 : 2.

80	92	71	34	17	2	1	0.5	20	63	17	2.69	41.8	3.4	170	248	1775	2469	1800	2720	91.1	89.1
81	49	14	8	5	3	2	1	73	24	3	2.67	34.8	3.6	193	307	337	2420	1800	2720	91.1	89.1
82	92	67	30	13	7	4	3	18	75	7	2.62	35.1	2.1	193	307	337	2420	1800	2720	91.1	89.1
83	87	67	43	27	10	6	4	24	59	17	2.72	39.6	3.1	217	234	1403	1632	1875	3429	93.5	97.4
84	67	52	27	17	10	5	4	47	43	10	2.71	34.2	4.2	253	337	261	1414	1875	3429	93.5	97.4
85	84	64	39	25	16	8	6	26	58	16	2.69	38.2	2.7	216	330	261	1414	1875	3429	93.5	97.4
86	94	90	80	61	28	14	8	7	65	28	2.62	40.7	1.8	110	191	261	1414	1875	3429	93.5	97.4
87	72	41	21	13	10	6	4	48	42	10	2.63	21.8	3.8	307	518	261	353	2435	2133	2820	146.1
88	97	68	40	22	11	7	4	18	71	11	2.80	30.7	2.2	254	356	258	352	1428	2626	1711	2622
89	94	55	27	13	5	3	2	27	68	13	2.73	30.5	2.3	203	272	272	349	1935	2138	1900	2624
90	95	75	43	18	13	5	3	13	74	13	2.73	28.4	2.7	207	306	258	352	1935	2138	1900	2624
91	97	55	27	17	11	7	4	23	66	11	2.72	26.9	2.7	209	311	258	352	1392	3200	1711	2622
92	94	71	32	15	7	4	2	18	75	7	2.67	41.5	1.9	223	334	266	343	1507	2622	88.5	121.8
93	98	89	63	46	15	8	5	7	78	15	2.70	36.8	1.7	223	334	266	343	1507	2622	88.5	121.8
94	87	78	65	13	2	2	2	18	80	2	2.69	40.4	1.3	264	271	228	270	1507	2622	88.5	121.8
95	94	80	46	18	6	3	2	12	82	6	2.66	31.8	1.9	260	360	272	349	1682	2281	1900	2624
96	60	32	21	17	9	4	2	58	33	9	2.72	28.2	4.7	260	360	272	349	1682	2281	1900	2624
97	97	87	67	43	24	7	6	7	69	24	2.69	32.4	2.1	156	213	251	370	1078	1817	1608	2612
98	97	85	55	43	25	12	6	10	65	25	2.63	44.8	2.5	183	230	246	279	1078	1817	1608	2612
99	84	58	36	23	12	7	4	31	57	12	2.68	31.6	2.8	214	360	310	374	1130	2310	1474	2385
100	99	82	36	20	7	4	3	12	81	7	2.53	38.7	2.2	146	238	260	314	1130	2310	1474	2385
101	56	14	4	2	1	2	2	68	31	1	2.51	34.1	2.6	203	271	246	316	1535	2480	1750	2630
102	93	77	50	27	10	6	4	13	87	8	2.90	40.1	1.7	155	222	227	347	926	1510	1910	3380
103	93	77	50	27	10	6	4	15	68	17	2.71	35.1	2.4	184	272	271	366	1495	2117	1620	3402
104	98	92	65	38	24	13	7	3	33	67	2.70	41.2	1.5	127	181	261	374	517	757	1414	2190
105	98	92	65	38	24	13	7	4	73	24	2.71	34.8	2.2	125	244	262	380	1093	1693	1911	2786
106	72	42	28	19	13	8	5	46	41	13	2.63	38.1	4.3	306	424	300	381	2790	4008	1712	2607
107	97	91	72	63	38	17	4	7	55	38	2.63	41.2	1.7	306	424	300	381	2790	4008	1712	2607
108	69	42	22	15	8	5	2	31	61	8	2.63	31.7	3.9	306	424	300	381	2790	4008	1712	2607
109	100	92	80	70	55	22	8	6	39	55	2.64	38.7	1.7	191	279	342	428	3116	3600	3487	3910
110	99	71	43	27	17	8	5	14	69	17	2.55	44.7	2.6	134	224	272	377	789	1988	1904	2410

^a Proportion of mortar mixture by weight 1 : 2.

^b Tested at the age of 18 days and 30 days, respectively.

^c Tarlac sand was used instead of Ottawa sand.

TABLE 8.—Granulometric composition and tensile and compressive strengths of Philippine sands—Continued.

Tracing No.	Granulometric analysis. Per cent particles passing through screen.										Three-screen analysis. Per cent particles.			Specific gravity.	Percentage of voids.	Uniformity coefficient.	Tensile strength in pounds per square inch (1.3 mortar).				Compressive strength in pounds per square inch (1.3 mortar).				Strength at the age of 28 days. Specimen $\times 100$. standard		
	10	20	30	40	50	60	80	100	200		Coarse.	Me- dium.	Fine.				Sand specimens.	7 days.	28 days.	7 days.	28 days.	7 days.	28 days.	7 days.			28 days.	7 days.	28 days.	Ten- sile.	Com- pressive.
111	72	31	9	3	2	1				55	43	2	2.37	50.3	2.6	244	281	257	354	1534	1998	1783	2328	79.4	85.8		
112	87	65	41	32	11	6	3	1	0.5	27	62	11	2.39	34.7	2.4	192	273	238	318	834	1870	1427	2130	86.1	87.8		
113	47	8	4	3	2	2	2	15	1	78	20	2	2.35	40.2	2.5	231	286	263	329	1258	1607	1427	2130	87.1	75.2		
114	60	34	18	13	8	4	2	2	1	56	36	8	2.46	36.1	4.2	204	261	263	329	1059	1376	1427	2130	79.5	64.5		
115	63	32	17	10	4	4	3	2	1	58	38	4	2.41	44.2	3.7	266	314	257	354	783	1878	1584	2804	88.6	66.8		
116	63	28	13	7	4	3	2	1	0.5	60	36	4	2.33	34.3	3.2	240	287	261	321	602	1113	657	1824	89.5	61.1		
117	82	38	16	8	5	3	2	1		40	55	5	2.30	32.1	2.6	192	303	275	389	1390	2220	1786	2410	78.1	92.1		
118	62	17	6	2	2	1	1	0.5		68	30	2	1.97	37.3	2.2	161	234	231	278	743	1250	1729	2002	84.1	61.8		
119	71	29	9	4	1	0.5				57	42	1	2.14		2.6	213	254	307	365	1548	2020	1657	2400	69.5	84.1		
120	99	97	40	7	2					2	96	2				435	502	307	365	3032	3974	1657	2400	137.1	165.1		
121	45	23	13	10	7	4	3	2	1	70	23	7				218	331	281	352	1682	2117	1898	2759	94.2	76.7		
122	98	83	50	26	16	10	7	4	2	7	77	16	2.67	30.2	2.3	219	323	237	384	1463	2550	2227	3770	84.1	67.6		
123	98	93	61	30	17	10	6	1		6	63	31	2.77	38.5	2.1	219	323	237	384	1463	2550	2227	3770	84.1	67.6		
124	78	57	38	25	13	5	2			32	55	13	2.57	41.9	4.1	154	239	294	369	946	1677	1488	2844	65.1	58.8		
125	94	65	16	7	3	2	2	2		25	72	3	2.63		1.7	188	249	219	325					76.5			
126	83	64	48	34	22	12	8	6	2	28	50	22	2.62	30.5	3.1	267	373	274	339	2375	3313	2274	2857	110.1	116.1		
127	60	28	17	12	8	5	4	3	2	40	52	8	2.67	30.1	5.1	159	330	199	337	1532	1997	1434	2041	98.1	97.7		
128	95	83	62	37	19	10	6	3	1	11	70	19	2.55	40.7	1.2	123	221	278	320	743	1471	1664	2972	69.1	49.5		
129	57	41	28	16	5	4	3	2	1	61	34	5	2.60	27.1	3.9	237	411	249	379	2155	2683	2249	2658	108.1	101.2		
130	68	43	28	19	11	7	5	4	2	31	58	11	2.64	30.1	4.1	151	284	199	337	1240	2180	1434	2041	84.5	106.5		
131													263	373		263	373										
132	94	75	53	37	28	19	14	8	3	17	55	28	2.69	37.3	3.1	289	414	255	310	1523	2403	1856	2108	133.1	114.1		
133	75	61	33	14	8	6	3	2	1	33	59	8	2.65	39.1	2.3	163	278	219	278	2006	2641	2517	3811	73.1	69.3		

134	98	70	14	3	2	2	1	1		17	81	2	2.68	39.3	1.3	200	261	252	340	798	1553	1364	2271	77.1	68.4
135	97	87	26	9	7	4	3	2	1	6	87	7	2.65	41.1	1.4	226	240	258	361	1784	2540	2504	3865	66.5	65.8
136																172	244								
137	98	96	81	37	20	7	5	2	1	2	78	20													
138	97	85	50	23	10	4	3	2	1	11	83	10	2.70	35.1	1.6	237	258	253	316	1635	2176	1829	2525	81.6	86.3
139	97	84	73	63	32	12	3	2	1	7	57	32	2.67	38.6	1.7	226	292	254	310	1570	2103	1856	2108	94.2	99.9
140	64	31	14	7	4	3	2	1	0.5	57	39	4	2.62	39.7	3.3	272	371	279	369	1812	3425	1733	3127	100.1	109.5
141	87	43	22	7	3	2	2	2		37	60	3	2.65	32.4	2.5	213	260	258	352	1779	2350	2053	2845	74.1	82.6
142	82	57	40	26	7	5	3	2		34	59	7	2.70	36.1	3.1	224	321	254	412	1600	2618	1740	3228	78.1	81.2
143	99	87	68	47	35	18	9	6	1	10	55	35	2.75	39.6	2.3	185	231	268	357	2020	2715	2240	2878	65.1	94.4
144	86	12	5	3	2	1.5	1	0.5		67	31	2	2.63	44.1	1.7	227	344	255	289	1759	2356	1872	3186	119	74.1
145	80	53	8	1					36	64			2.66	33.4	1.8	268	380	241	340	810	1660	1008	1320	112.1	126.1
146	97	85	58	43	22	15	9	7		11	67	22	2.70	36.8	2.8										
147	94	79	45	14	3	2	1	0.5		12	85	3	2.70	35.1	1.6	225	332	235	326	1340	2230	1790	2370	102.1	94.1
148	94	67	34	15	7	4	3	2	2	20	73	7	2.53	38.1	2.1	146	228	215	339	759	1666	1725	2177	87.3	76.6
149	72	29	10	5	5	2	1	0.5		52	43	5	2.48	34.3	2.5	211	310	234	328	1194	2608	1650	2375	94.5	109.8
150	92	76	56	33	19	11	7	5	2	16	65	19	2.73	37.6	2.4	199	328	266	422	1220	2385	1540	2981	77.8	80.1
151	98	96	88	68	28	14	9	5	1	3	69	28	2.75	40.1	1.7	142	230	262	331	697	1356	1724	2370	69.5	57.2
152	92	82	65	43	30	14	7	3	1	12	58	30	2.75	34.9	2.1	212	320	276	352	1339	2325	1772	3040	91.1	76.5
153	98	97	88	58	30	12	6	3	1	3	67	30	2.77	39.1	1.8	135	239	262	331	691	1375	1724	2370	72.2	53.8
154	95	87	68	47	28	11	6	4	2	8	64	28	2.60	39.0	2.1	142	285	236	349	698	1526	1410	2316	81.6	65.9
155	97	84	70	57	30	15	7	3		13	57	30	2.62		1.9	260	310	243	359					86.4	
156	96	89	75	66	35	20	1	1		7	58	35	2.61	40.1	2.1	231	324	265	341					95.1	
157	89	75	55	36	24	15	9	7	2	18	58	24	2.63	27.4	2.8	200	349	276	355	1293	2415	1601	2211	98.4	104.5
158	87	67	52	34	25	17	13	11	8	23	52	25	2.63	39.1	4.7	240	359	253	363	1358	2137	1729	2482	99.1	86.1
159	83	67	53	37	25	14	8	7	2	24	51	25	2.65	25.9	3.1	180	317	253	341	1433	2566	1698	2512	93.1	102.1
160	91	74	48	27	13	7	3	2	1	17	70	13	2.65	36.7	2.3	218	328	284	407	1384	2665	1921	2973	80.7	89.7
161	78	61	44	28	20	13	10	8	2	30	46	10	2.73	45.7	3.7	322	467	250	351	1727	3869	1616	2505	133.1	154.3
162	75	42	27	16	10	7	4	3	2	44	46	10			3.8	203	291	221	345	1858	3012	1481	3144	86.8	95.6
163	91	41	16	11	5	2	1	1		41	54	5	2.58	37.6	2.6	274	338	275	320					105.6	
164	57	25	9	6	3	2	2	1		62	35	3	2.22	36.1	2.9	242	275	304	373	1345	1665	1456	2088	73.8	79.8
165	90	64	47	29	16	4	2	1		42	66	16				247	330	259	392	893	1613	1362	2257	84.7	71.6
166	77	39	18	11	6	3	2	2		48	46	6	2.45	45.1	3.1	239	321	275	320					100.1	

Mortar mixture by weight 1 : 2.

TABLE 8.—Granulometric composition and tensile and compressive strengths of Philippine sands—Continued.

Tracing No.	Granulometric analysis.										Three-screen analysis.			Specific Gravity.	Percentage of voids.	Uniformity coefficient.	Tensile strength in pounds per square inch (1:3 mortar).				Compressive strength in pounds per square inch (1:3 mortar).				Strength at the age of 28 days.									
	Per cent particles passing through screen.										Per cent particles.						Tensile strength in pounds per square inch (1:3 mortar).				Compressive strength in pounds per square inch (1:3 mortar).													
	10		20		30		40		50		60		80				100		200		Coarse.	Me- dium.	Fine.	Sand specimens.		Standard sand.		Sand specimens.		Standard sand.		Ten-sile.	Com- pressive.	
167	98	82	37	18	3	2	1	1	---		10	87	3	2.58	44.5	2.1	214	259	275	320												81.1		
168	73	42	25	15	10	6	4	3	1		45	45	10	2.63	40.1	3.6	305	310	237	311	1510	2142	1287	1949	99.8	110.1						99.8	110.1	
169	99	64	38	23	14	7	5	3	---		18	68	14	2.64	45.7	2.7	111	164	244	350	742	1485	1803	2397	46.8	62.1						46.8	62.1	
170	72	27	10	6	3	3	2	2	1		43	54	3	2.62	30.1	2.3	171	283	313	325	1630	2516	1490	2218	87.1	114.1						87.1	114.1	
171	78	10	5	4	3	2	2	1	0		64	33	3	2.70	37.9	1.7	290	370	254	354	3049	4721	2050	2704	104.5	174.6						104.5	174.6	
172	83	59	42	18	10	7	5	3	2		32	58	10	2.54	29.4	2.6	301	386	216	338	1772	2654	1482	2473	114.2	107.1						114.2	107.1	
173	90	68	56	28	9	8	7	4	3		32	59	9	2.44	41.1	2.7	168	244	225	313	993	1960	1433	1996	78.1	98.2						78.1	98.2	
174	75	30	12	6	4	2	1	0.5	---		50	46	4	2.77	43.1	2.6	258	347	281	388	2370	4390	2230	3738	89.5	117.3						89.5	117.3	
175	88	57	33	22	17	12	8	7	4		30	53	17	2.67	33.4	4.1	244	355	249	337	1469	2724	1454	2174	105.2	125.3						105.2	125.3	
176	78	50	28	17	12	9	6	3	---		37	51	12	2.65	29.3	3.6	256	367	333	423	1657	2640	1660	2211	86.8	119.3						86.8	119.3	
177	90	65	48	36	28	19	12	8	3		23	49	28	2.66	34.1	4.1	189	249	246	343	1258	2350	1794	2742	72.6	85.7						72.6	85.7	
178	97	85	65	43	25	12	5	3	1		8	67	25	2.64	41.8	2.1	118	169	246	343	650	1235	1794	2742	49.3	45.1						49.3	45.1	
179	97	86	68	50	37	22	14	8	3		6	57	37	2.76	41.9	2.7	140	220	246	343	856	1415	1794	2742	64.2	51.6						64.2	51.6	
180	99	92	60	43	15	7	4	2	---		7	78	15	2.73	49.8	2.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
181	98	96	95	93	80	50	22	8	2		3	17	80	2.65	47.1	1.7	193	291	277	400	1147	1338	2173	3452	73.1	38.7						73.1	38.7	
182	98	94	86	68	44	27	17	8	2		4	52	44	2.85	40.2	2.1	164	214	243	343	715	1420	1794	2742	62.4	51.7						62.4	51.7	
183	98	92	61	36	22	12	7	4	2		3	75	22	2.83	36.7	2.1	175	264	289	414	988	2359	1819	2678	63.8	88.2						63.8	88.2	
184	75	57	48	38	29	21	12	8	2		34	37	29	2.80	31.4	6.3	201	321	246	343	1810	3370	2150	3800	93.8	88.7						93.8	88.7	
185	96	80	57	37	23	11	7	3	2		10	67	23	2.49	37.6	2.5	58	102	246	343	375	515	1794	2742	30.1	18.9						30.1	18.9	
186	98	97	92	76	56	20	6	3	---		2	42	56	2.82	44.6	1.4	190	266	270	384	1245	1660	1970	2935	69.3	56.6						69.3	56.6	
187	87	64	41	27	18	11	7	5	2		23	59	18	2.83	45.1	3.2	230	322	262	367	1426	2656	1600	2500	87.8	106.1						87.8	106.1	
188	93	74	47	28	16	9	6	3	2		16	68	16	2.78	37.1	2.5	119	202	246	343	1112	2140	1794	2742	59.1	78.1						59.1	78.1	
189	77	52	36	23	14	7	3	2	1		36	50	14	2.78	34.1	5.1	223	281	246	343	1655	2900	1794	2742	82.1	105.7						82.1	105.7	

190	87	74	63	57	52	46	23	13	---	21	27	52	2.72	---	1.9	231	340	327	436	2801	3694	3316	3612	78.1	102.4	
191	---	97	87	67	26	13	8	5	2	2	72	26	2.64	42.1	1.6	148	190	234	318	656	999	1690	2445	59.8	40.8	
192	100	94	68	38	21	8	5	3	2	4	75	21	2.69	41.1	2.1	145	210	300	342	876	1194	1476	2896	61.4	41.3	
193	---	---	---	97	92	85	70	25	7	2	0	15	85	2.68	38.3	1.1	134	163	264	334	606	945	1543	2481	48.8	38.1
194	99	96	88	76	57	21	14	8	2	2	3	40	57	2.64	43.3	2.2	125	171	300	342	515	722	1516	2002	50.1	36.1
195	---	98	96	86	55	17	7	3	2	0	45	55	2.69	37.6	1.3	99	160	264	334	595	1136	1543	2481	48.1	45.7	
196	---	98	94	86	74	45	20	12	3	0	26	74	2.71	39.3	1.8	94	128	264	334	519	925	1543	2481	38.4	37.2	
197	---	97	78	48	27	13	9	6	2	2	71	27	2.66	41.1	1.9	139	185	234	318	767	1164	1690	2445	58.2	47.7	
198	76	37	11	5	2	1	0.5	---	---	48	50	2	2.74	36.2	2.4	231	---	---	---	---	3946	---	5004	---	78.4	---
199	98	84	45	20	11	7	4	3	1	8	81	11	2.63	41.3	2.1	138	228	246	343	756	1950	1794	2742	66.5	71.1	
200	88	67	52	42	32	18	12	7	2	23	45	32	2.70	36.1	3.5	257	368	252	353	1367	2665	1747	2596	104.3	102.8	
201	98	81	36	22	13	8	3	1	---	11	76	13	2.70	35.1	2.4	314	428	313	403	2520	3820	2586	3100	106.2	107.2	
202	---	99	97	93	87	72	48	25	1	0	13	87	2.73	41.1	1.7	110	188	256	334	400	887	1700	2400	56.4	36.9	
203	96	74	52	27	15	8	5	4	1	1.6	69	15	2.75	37.9	2.2	234	320	256	334	1789	2650	1700	2400	96.1	110.3	
204	95	79	48	28	18	12	7	5	---	14	68	18	2.55	39.1	2.7	220	314	315	386	1225	1731	1970	2340	81.2	74.2	
205	98	88	67	43	24	12	8	5	2	4	72	24	2.76	41.3	2.3	196	293	247	342	971	2008	1663	2680	85.8	74.7	
206	93	69	45	22	11	6	3	2	---	17	72	11	2.69	42.2	2.3	124	196	221	326	792	1711	1623	2300	60.2	74.5	
207	74	43	22	8	3	2	---	---	---	44	53	3	2.61	34.1	2.7	166	283	227	347	1440	2080	1910	3380	81.5	61.5	
208	90	58	31	15	7	2	1	---	---	25	68	7	2.50	38.1	2.3	182	216	361	389	834	1480	1868	2580	55.5	57.4	
209	99	86	52	27	13	8	6	3	2	7	80	13	2.71	44.2	2.1	---	---	---	---	---	---	---	---	---	---	---
210	98	84	48	29	18	10	5	2	0	9	74	18	2.63	41.6	2.4	---	---	---	---	---	---	---	---	---	---	---
211	40	10	5	3	2	1	---	---	---	78	20	2	2.70	32.9	2.9	394	589	335	458	2608	5508	1508	2827	128.1	195.1	
212	97	88	71	45	25	13	8	5	1	8	67	25	2.65	33.7	2.1	190	315	235	371	1475	2391	2113	3180	85.1	75.2	
213	98	73	40	23	9	3	2	1	0	15	76	9	2.79	38.1	2.1	217	338	252	308	1644	2322	1356	2235	109.8	104.1	
214	98	88	66	47	27	13	7	3	1	5	68	27	2.51	48.1	2.2	280	354	512	522	2255	3305	4370	5080	68.1	65.2	
215	82	50	32	18	12	6	4	3	1	36	52	12	2.58	31.1	3.3	286	302	272	342	2154	3016	2065	2609	88.3	115.6	
216	98	92	76	61	28	15	7	1	---	5	67	28	2.64	36.2	1.8	---	---	---	---	2559	4327	3201	4637	---	93.7	
217	95	89	80	52	27	12	4	2	1	9	64	27	2.71	38.7	1.9	247	342	281	323	---	---	---	106.0	---	---	
218	72	54	35	22	13	8	7	4	2	38	49	13	2.80	32.1	3.7	361	528	288	410	2350	3398	1800	2693	112.9	112.6	
219	97	91	67	44	18	8	4	3	1	6	78	18	2.60	35.1	1.7	166	290	288	410	741	1433	1800	2693	70.7	53.3	
220	100	97	78	60	28	10	4	3	1	2	70	28	2.20	41.6	2.5	160	217	281	343	774	938	1279	2030	63.3	46.1	
221	99	94	86	74	56	50	25	6	2	3	41	56	2.64	36.1	1.6	107	263	245	345	690	1610	1654	2639	76.2	61.1	
222	77	33	21	16	12	8	7	4	2	46	42	12	2.54	33.1	4.1	246	345	245	345	1786	3188	1654	2639	100.0	121.2	
223	93	27	4	3	2	2	1	0	40	58	2	2.59	36.1	1.7	166	192	245	345	1193	2050	1654	2639	55.6	78.1		
224	97	28	16	12	10	7	5	4	2	40	50	10	2.58	41.1	3.3	101	228	245	345	812	1950	1654	2639	66.1	68.3	

TABLE 8.—Granulometric composition and tensile and compressive strengths of Philippine sands—Continued.

Track- ing No.	Granulometric analysis. Per cent particles passing through screen.										Three-screen analysis. Per cent particles.			Specific gravity.	Percentage of voids.	Uniformity coefficient.	Tensile strength in pounds per square inch (1:3 mortar).				Compressive strength in pounds per square inch (1:3 mortar).				Strength at the age of 28 days. Specimen standard × 100.						
											Coarse.	Me- dium.	Fine.																		
																	Sand specimens.		Standard sand.		Sand specimens.		Standard sand.								
	10	20	30	40	50	60	80	100	200								7 days.	28 days.	7 days.	28 days.	7 days.	28 days.	7 days.	28 days.			7 days.	28 days.	Ten- sile.	Com- pressive.	
225	84	57	41	28	22	17	12	8	1	34	44	22	2.50	39.9	4.8	147	210	317	356	562	821	1161	1731	59.1	47.4						
226	67	38	24	16	11	6	4	2	1	50	39	11	2.63	35.1	4.3	264	341	258	353	1934	3164	1572	2729	96.7	116.1						
227	65	17	8	7	5	4	3	2	1	68	27	5	2.63	35.9	2.5	285	405	277	404	2286	3335	1594	3247	100.1	102.6						
228	58	13	5	3	2	1	0.5			73	25	2	2.64	34.4	2.3	321	432	277	404	2633	3836	1594	3247	107.1	118.1						
229	86	72	57	50	35	25	16	9		24	41	35	2.57	36.8	3.8	170	220	263	370	544	1202	1427	2130	59.4	56.4						
230	36	74	10	8	7	5	3	3	0	79	14	7	2.59	33.7	4.8	245	374	263	370	1268	2294	1427	2130	101.1	107.8						
231	89	53	20	7	3	2	1			23	74	3	2.52	36.4	2.1	154	214	259	367	631	1254	1784	2700	58.3	46.5						
232	65	19	7	4	3	2	1			62	35	3	2.63	35.7	2.4	339	405	245	385	2235	3908	1444	2241	105.2	174.1						
233	86	59	38	24	10	5	2	1		28	62	10	2.61	45.7	2.4	209	298	270	334	317	661	912	1450	89.5	45.5						
234	84	57	38	25	16	10	6	3	1	32	52	16	2.66	39.1	3.2	243	358	273	334	738	1298	912	1450	107.1	89.5						
235	77	30	13	7	5	3	2	1		44	51	5	2.64	33.2	2.2	231	364	264	346	1508	2574	1681	2189	105.2	117.6						
236	22	10	7	5	4	3	2	1		87	9	4	2.78	36.8	3.4	339	509	261	374	2657	3760	1414	2190	136.1	171.8						
237	93	62	30	16	8	5	4	3	2	20	72	8	2.45	37.1	2.2	238	301	361	389	1360	2020	1868	2580	77.5	78.4						
238	90	54	24	12	6	2	1			29	65	6	2.50	43.2	2.7	222	294	289	392	1606	2708	1886	2730	75.1	99.3						
239	98	82	54	20	12	7	2	1		8	80	12	2.67	42.8	2.1	176	251	243	370	1154	1722	1584	2546	67.7	67.6						
240	89	56	24	12	8	6	4	3	2	24	68	8	2.52	36.1	2.4	252	315	361	389	1270	1780	1868	2580	81.1	69.1						
241	97	72	46	28	17	8	5	3	1	13	70	17	2.51	44.7	2.6	102	202	229	375	469	1184	1444	2365	54.1	50.2						
242	96	68	30	15	9	6	4	3	2	17	74	9	2.52	38.7	2.1	127	258	215	339	768	1632	1728	2177	76.2	75.1						
243	91	66	37	22	13	7	4	2	2	21	66	13	2.55	40.7	2.7	136	211	241	392	695	1424	1637	2451	54.1	58.1						
244	96	62	31	16	7	4	3	2	1	21	72	7	2.58	34.1	2.1	156	262	228	330	1082	1983	1328	2263	79.4	87.5						
245	82	47	20	10	5	3	2	2	1	18	77	5	2.62	39.1	2.6	242	336	320	415	1690	3260	2380	3610	81.1	90.5						
246	98	94	82	65	47	23	13	8	3	4	49	47	2.69	45.1	2.1	212	344	251	370	880	1917	1811	2762	93.1	69.3						
247	83	55	29	14	8	4	3	2		30	62	8	2.70	42.1	2.5	253	375	270	392	1515	3509	1913	3777	95.6	95.2						

248	92	64	46	33	26	17	11	8	1	24	50	26	2.68	38.6	3.8	183	305	235	310	1564	2389	1670	2248	98.5	106.2
249	96	68	40	22	12	7	4	3	2	17	71	12	2.57	40.1	2.5	197	298	286	403	1329	1983	2100	2722	73.9	72.8
250	84	56	37	23	14	7	4	3	1	31	55	14	2.49	38.1	3.2	188	322	260	389	1375	2720	1769	3040	82.7	89.5
251	78	49	26	15	9	6	3	1	---	38	53	9	2.61	40.3	3.4	197	312	316	402	779	2199	1704	2425	77.7	90.5
252	96	71	37	18	12	6	4	3	2	15	73	12	2.55	36.1	2.5	159	232	255	365	1313	1832	1920	2777	66.6	66.1
253	87	65	47	35	25	17	13	10	5	22	53	25	2.58	32.9	2.8	130	234	255	365	1180	2060	1920	2777	64.1	74.2
254	97	77	44	27	15	9	4	3	2	12	73	15	2.62	45.7	2.5	90	162	283	364	725	1181	1523	2861	44.3	41.3
255	78	57	41	29	19	11	6	3	0	33	48	19	2.59	38.7	3.7	225	352	310	432	1818	2405	2631	3428	81.4	70.2
256	85	66	47	34	22	12	8	5	---	26	52	22	2.56	40.3	2.9	216	309	265	325	854	1149	1648	2618	95.1	44.1
257	95	74	54	36	24	13	7	4	1	14	62	24	2.61	35.4	2.6	235	350	277	364	1604	2930	1517	2928	96.2	100.1
258	84	62	43	34	22	12	7	5	2	29	49	22	2.62	30.6	3.4	218	309	251	325	1505	2597	1560	2464	95.1	105.2
259	97	81	50	28	16	7	3	2	1	5	76	16	2.65	38.7	2.2	217	338	265	389	1180	2538	1600	2606	86.8	97.3
260	95	77	38	13	10	2	1	1	---	8	85	10	2.65	47.1	1.8	183	313	262	367	1134	2003	1600	2500	85.3	80.3
261	94	77	56	37	24	13	7	4	2	13	63	24	2.54	32.2	2.5	193	268	277	364	1417	2545	1517	2928	73.5	86.8
262	98	94	82	60	32	12	4	3	2	13	64	32	2.76	37.1	2.7	221	286	257	312	1270	2550	1700	3040	90.1	65.7
263	95	74	48	30	20	11	7	4	2	13	67	20	2.70	39.1	1.8	185	281	257	312	1270	2000	1700	3040	90.1	65.7
264	87	60	37	18	10	4	2	1	---	27	63	10	2.91	33.7	2.7	274	389	255	338	1536	3631	2089	2703	115.1	134.1
265	95	80	50	18	13	8	6	3	2	11	76	13	2.67	31.3	2.1	231	333	233	347	1343	2146	1718	2527	96.1	85.1
266	88	66	38	18	7	3	2	1	1	18	75	7	2.83	33.1	2.3	214	279	255	338	1571	2706	2089	2703	82.5	100.1
267	93	70	43	17	7	3	2	2	1	17	76	7	2.71	30.2	2.1	216	300	253	315	1959	3083	1829	2525	95.2	122.1
268	98	94	70	37	18	9	6	4	2	2	80	18	2.68	32.1	2.1	218	279	246	356	1198	1800	1562	2610	78.6	69.1
269	98	89	73	45	23	12	8	7	5	7	70	23	2.77	34.8	2.1	170	235	208	290	923	1801	1375	2512	81.1	71.8
270	95	78	66	54	30	10	3	---	---	15	55	30	2.58	41.1	1.8	139	204	223	338	803	1311	1636	2622	60.1	50.1
271	92	64	27	12	5	2	2	2	1	22	73	5	2.77	33.8	2.1	207	368	267	419	1720	3012	2506	4197	88.1	72.1
272	97	90	79	36	25	14	10	7	2	4	71	25	2.66	32.7	2.1	175	284	247	368	1102	1900	1799	2585	77.2	73.5
273	97	78	44	17	7	4	2	2	1	12	81	7	2.60	32.1	1.7	213	277	275	351	1225	2028	1478	2353	79.1	86.4
274	100	97	77	35	17	7	4	2	1	0	83	17	2.72	33.4	1.6	202	278	267	376	1911	2795	2758	3411	74.1	80.7
275	100	92	77	60	45	12	7	3	2	5	50	45	2.71	31.5	1.6	181	271	281	352	1324	2188	1897	2595	77.1	84.4
276	97	75	36	12	4	3	2	2	2	10	86	4	2.73	33.1	1.5	196	308	243	326	1791	2824	2139	3934	94.5	72.1
277	93	78	47	29	18	7	6	4	2	15	67	18	2.68	32.9	2.4	223	322	234	355	1343	2481	1893	2406	90.8	103.1
278	98	95	83	59	33	12	5	3	1	3	64	33	2.68	42.1	1.8	201	248	265	339	946	1420	1520	2820	73.3	50.4
279	98	75	45	27	18	11	8	7	3	10	72	18	2.80	40.1	2.8	200	314	244	381	1414	2340	1848	2610	82.5	89.5
280	98	90	67	30	15	7	4	2	1	5	80	15	2.70	31.9	1.7	164	218	230	320	995	1749	1535	2311	68.1	75.6
281	81	46	31	23	12	7	5	4	3	43	45	12	2.78	29.1	2.1	181	311	232	334	1887	3418	1677	2340	93.3	146.1
282	96	62	31	17	8	4	3	2	---	20	72	8	2.69	34.9	2.2	148	332	227	373	1036	2558	1394	2220	123.1	115.1

TABLE 8.—Granulometric composition and tensile and compressive strengths of Philippine sands—Continued.

Tracing No.	Granulometric analysis, Per cent particles passing through screen.										Three-screen analysis, Per cent particles.			Specific gravity.	Percentage of voids.	Uniformity coefficient.	Tensile strength in pounds per square inch (1:3 mortar).				Compressive strength in pounds per square inch (1:3 mortar).				Strength at the age of 28 days. Specimen standard $\times 100$.
																	Sand specimens.		Standard sand.		Sand specimens.		Standard sand.		
	10	20	30	40	50	60	80	100	200	Coarse.	Me- dium.	Fine.	7 days.				28 days.	7 days.	28 days.	7 days.	28 days.	7 days.	28 days.	Ten- sile.		Com- pressive.
283	99	91	65	28	8	3	2	1	---	4	88	8	2.71	38.4	1.4	148	249	287	360	1031	1999	1567	2950	69.2	67.7
284	94	72	40	16	7	4	3	2	---	16	77	7	2.76	35.1	2.1	172	218	247	341	1410	2358	1770	2290	64.1	103.1
285	98	92	63	32	14	7	5	3	2	5	81	14	2.71	33.7	1.8	141	242	210	322	860	1715	1457	2627	75.2	65.2
286	98	93	72	30	17	8	4	3	2	4	79	17	2.73	40.3	1.7	186	240	252	344	1193	1837	1715	2473	70.1	74.2
287	100	98	77	45	24	12	3	1	0	2	74	24	2.72	34.1	1.8	172	242	260	341	982	1735	1596	2217	71.1	79.1
288	100	95	66	31	15	7	5	2	1	3	82	15	2.77	33.2	1.7	185	269	257	324	1101	1978	1478	2253	83.1	87.7
289	98	89	62	25	7	3	2	2	1	5	88	7	2.73	33.5	1.4	175	285	223	549	696	2871	1229	4734	51.9	60.8
290	93	75	43	20	12	6	3	2	1	20	63	12	2.67	32.6	2.1	189	331	242	341	1756	2714	1902	3023	97.2	89.8
291	83	47	29	16	6	4	2	2	1	40	54	6	2.71	29.1	3.0	326	432	251	373	2759	3233	2260	3406	115.6	95.1
292	76	24	2	1	---	---	---	---	---	57	43	0	2.17	51.5	2.3	332	378	---	---	3140	3700	---	---	---	---
293	84	61	36	25	16	8	3	2	---	28	56	16	2.92	38.6	2.8	335	428	367	351	1662	2164	2030	2654	122.1	81.7
294	83	52	34	18	10	4	3	2	---	37	53	10	2.63	32.1	3.1	296	470	259	371	1493	2577	1901	2940	124.1	87.8
295	86	74	60	42	27	12	7	3	---	20	53	27	2.58	37.4	2.3	175	265	310	432	803	1439	2630	3428	60.5	42.1
296	91	77	59	38	23	8	5	3	2	18	59	23	2.51	39.1	2.1	194	287	266	367	926	1649	2102	2491	78.2	66.2
297	89	81	68	46	29	13	6	3	2	14	57	29	2.62	34.5	2.1	160	260	266	367	801	1456	2102	2491	70.8	58.5
298	66	42	28	17	10	5	3	2	1	47	43	10	2.77	31.9	4.1	279	374	280	334	1704	3565	1676	2472	112.1	144.5
299	86	66	43	23	13	7	2	1	---	25	62	13	2.67	34.8	2.3	174	256	280	334	957	1988	1676	2472	107.1	80.5
300	87	65	42	25	12	7	3	1	---	23	65	12	2.69	37.1	2.5	211	315	211	343	1418	2527	1448	2807	92.1	90.1
301	70	43	24	13	8	4	3	2	1	46	46	8	2.65	34.1	3.4	209	325	255	349	1343	2807	1393	3022	91.1	93.5
302	66	26	---	---	---	---	---	---	---	---	---	---	2.88	56.1	1.7	169	---	197	---	2087	---	---	---	---	---
303	96	89	77	68	48	26	9	3	---	8	44	48	2.60	27.5	1.7	270	---	---	340	3245	4288	79.4	---	75.8	
304	87	66	52	35	20	11	7	4	1	24	56	20	2.43	27.5	2.7	192	252	212	302	1200	1660	1650	2465	83.5	67.2
305	77	50	30	17	11	7	6	4	2	40	49	11	2.78	30.2	3.4	262	429	258	334	2161	3408	2385	3228	127.1	105.3

306	78	39	22	13	9	7	4	3	2	44	47	9	2.67	29.7	3.5	276	400	282	333	1565	2815	1714	2318	120.1	121.6
307	85	75	61	38	20	12	7	4	2	26	54	20	2.63	31.6	2.6	222	345	236	343	1670	2620	1900	2550	101.1	104.1
308	78	48	28	18	12	8	5	4	2	40	48	12	2.65	26.1	3.7	192	312	235	330	1860	3374	1896	2671	94.7	126.3
309	87	66	45	26	17	10	7	5	2	23	60	17	2.65	27.5	2.9	171	277	235	330	1260	2094	1896	2671	84.1	78.4
310	88	67	43	26	17	10	7	5	2	25	58	17	2.66	28.7	2.8	195	289	235	330	1442	2691	1896	2671	87.5	100.8
311	81	56	37	20	10	4	2	1	0	32	58	10	2.68	26.9	2.8	227	314	235	330	1848	2749	1896	2671	95.2	103.1
312	78	49	27	13	7	3	2	1	---	36	57	7	2.60	32.1	2.9	248	318	249	318	1430	2210	1700	2460	100.0	90.1
313	63	34	18	12	7	4	3	2	1	53	40	7	2.69	32.1	4.3	281	372	298	390	1480	2750	2190	3450	95.1	80.1
314	71	46	27	15	9	6	3	2	---	44	47	9	2.64	32.5	3.8	203	317	224	340	1117	2510	1767	2932	93.1	85.6
315	62	26	12	17	5	3	2	1	---	57	38	5	2.66	34.5	3.2	251	405	266	391	1235	3340	1387	3045	104.1	109.7
316	77	39	17	7	3	2	---	---	---	46	51	3	2.65	35.5	2.7	267	343	254	370	1604	3046	1673	2435	93.1	125.1
317	87	70	54	41	32	26	17	14	10	34	34	32	2.71	34.8	5.7	276	364	276	350	2414	2947	2218	3506	104.1	84.1
318	94	63	20	10	5	2	1	---	---	22	73	5	2.58	44.2	1.7	211	280	281	354	1534	1929	2028	3626	70.1	52.8
319	84	54	47	36	25	17	13	9	3	38	47	25	2.67	35.1	4.6	315	395	281	398	2106	3558	2026	2626	99.5	135.2
320	98	89	60	32	18	8	3	2	---	5	77	18	2.71	35.6	2.1	---	340	---	400	---	1649	---	2340	85.1	70.3
321	76	47	27	15	13	7	5	4	2	41	46	13	2.84	37.5	3.3	257	381	274	340	1707	3375	1678	2426	112.1	139.2
322	80	42	22	12	7	4	3	2	---	44	49	7	2.42	40.3	3.1	114	189	274	340	508	980	1678	2426	55.6	40.4
323	99	91	65	42	29	18	12	5	---	3	68	29	2.87	37.6	2.4	263	348	274	340	2088	3055	1678	2426	102.3	126.1
324	52	26	7	2	1	---	---	---	---	63	36	1	2.46	37.1	3.4	130	252	229	342	972	1331	1965	3011	73.5	44.3
325	78	56	33	21	12	7	4	3	---	32	56	12	2.50	37.1	3.1	152	276	229	342	984	1699	1965	3011	80.8	56.4
326	94	44	7	2	0	---	---	---	---	30	70	0	2.94	35.1	1.7	196	294	274	340	1625	2530	1678	2426	86.5	104.2
327	84	42	25	17	13	8	7	5	2	41	46	13	2.83	37.9	3.9	217	340	274	340	1601	2775	1678	2426	100.0	114.2
328	100	99	98	95	77	47	25	3	---	23	77	27	2.61	46.9	1.5	161	206	253	300	---	---	---	---	68.7	---
329	69	22	1	0	0.1	---	---	---	---	62	38	0	2.77	39.1	2.3	330	457	326	330	1392	4124	1735	2975	138.2	138.6
330	98	71	26	10	3	2	1	---	---	18	79	3	2.63	43.3	1.8	176	246	262	344	1037	1790	1995	2970	76.2	60.3
331	96	79	40	22	12	7	4	3	2	12	76	12	2.64	41.5	2.3	164	262	247	344	1037	1790	1995	2970	76.2	60.3
332	94	43	17	7	4	3	2	1	---	30	66	4	2.77	35.1	2.5	292	365	259	369	1810	3155	1673	2377	99.1	132.6
333	98	63	32	14	6	3	2	1	---	12	82	6	2.62	38.1	1.8	239	320	260	344	1520	2279	1920	2830	93.1	80.5
334	100	95	78	55	33	7	3	2	1	3	64	33	2.89	31.4	1.6	228	309	269	373	1550	2246	2107	2846	82.7	79.1
335	67	18	5	3	2	1	0.5	---	---	60	38	2	2.63	36.1	2.3	230	355	207	337	1638	2915	1525	2224	105.2	131.1
336	97	68	33	17	9	3	2	1	---	16	75	9	2.99	32.9	2.3	222	373	207	337	1693	3269	1525	2224	111.6	146.7
337	92	75	24	15	8	4	3	2	---	14	78	8	2.66	38.4	2.1	205	291	285	362	1068	1849	1783	3136	80.4	59.1
338	98	92	73	52	37	23	16	8	3	4	59	37	2.81	42.1	2.4	179	281	227	339	918	2180	1239	2598	53.3	84.1

a Proportion of mortar mixture by weight 1 : 2.

TABLE 8.—Granulometric composition and tensile and compressive strengths of Philippine sands—Continued.

Tracing No.	Granulometric analysis. Per cent particles passing through screen.										Three-screen analysis. Per cent particles.			Specific Gravity.	Percentage of voids.	Uniformity coefficient.	Tensile strength in pounds per square inch (1:3 mortar).				Compressive strength in pounds per square inch (1:3 mortar).				Strength at the age of 28 days. Specimen $\times 100$, standard			
											Coarse.		Me- dium.				Fine.		Sand specimens.		Standard sand.		Sand specimens.				Standard sand.	
											7 days.	28 days.					7 days.	28 days.	7 days.	28 days.	7 days.	28 days.	7 days.	28 days.				
	10	20	30	40	50	60	80	100	200																			
339	98	76	33	7	3	1	---	---	---	---	8	89	3	2.51	44.2	1.8	147	242	255	390	868	1621	1756	2688	62.1	60.4		
340	87	60	31	16	10	4	3	2	---	---	26	64	10	2.68	43.3	2.5	192	307	277	393	1358	2472	1700	2578	78.2	96.2		
341	97	85	54	28	17	7	4	3	1	---	6	77	17	2.84	39.1	2.1	254	323	252	343	1183	2027	1945	2404	94.1	84.2		
342	79	58	38	22	15	8	4	3	1	---	32	53	15	2.51	30.3	3.1	162	247	334	392	1042	2110	1736	2350	63.1	90.1		
343	92	75	58	40	24	10	7	4	1	---	17	59	24	2.67	40.1	2.2	111	195	247	417	1026	2084	1590	3367	79.0	61.8		
344	98	84	55	28	14	7	4	3	2	---	10	76	14	2.59	44.4	2.1	112	171	236	366	1014	1541	1758	3200	46.8	48.2		
345	88	78	67	42	23	13	7	4	2	---	22	55	23	2.67	41.2	2.5	173	283	259	344	1480	2454	1707	3176	82.3	77.3		
346	80	53	30	17	8	3	2	1	---	---	34	58	8	2.70	40.1	2.7	243	347	260	369	1304	2563	1673	2377	94.1	108.8		
347	81	57	38	26	17	9	4	3	2	---	33	50	17	2.78	39.5	3.5	200	308	247	342	1163	2346	1663	2568	90.1	91.5		
348	96	67	43	27	16	10	6	4	2	---	18	66	16	2.80	47.7	3.1	188	311	263	365	971	1928	1570	2590	85.2	74.4		
349	98	96	83	65	21	11	6	3	---	---	2	77	21	2.63	41.7	1.6	150	229	259	363	598	894	1116	1956	62.3	45.7		
350	98	86	51	34	13	7	4	2	---	---	2	85	13	2.69	40.5	2.2	217	299	314	386	876	1534	1143	2078	77.5	74.1		
351	99	85	54	27	14	8	3	2	---	---	7	79	14	2.86	44.5	---	271	346	295	343	974	2135	1642	2025	101.5	105.2		
352	58	27	14	8	5	3	2	1	---	---	62	33	5	2.71	36.7	3.7	290	382	257	354	2485	2995	1783	2878	108.1	104.2		
353	---	86	65	54	28	16	---	---	---	---	12	60	28	2.62	---	2.2	215	258	276	348	---	---	---	---	74.2	---		
354	---	76	44	32	17	9	---	---	---	---	15	68	17	2.63	---	2.6	226	263	276	348	---	---	---	---	75.5	---		
355	97	87	72	54	37	15	8	7	3	---	7	56	37	2.66	38.7	1.7	201	329	283	372	1413	1855	2394	3677	88.4	50.5		
356	98	61	25	12	8	4	3	2	---	---	20	72	8	2.64	40.1	2.1	220	334	246	335	1830	2608	2102	2712	99.7	96.2		
357	97	87	70	50	33	20	12	6	2	---	7	60	33	2.59	38.1	2.2	233	343	261	405	1213	2011	1503	2552	84.8	78.8		
358	100	98	93	88	---	50	---	15	---	---	---	53	47	2.65	42.5	2.8	208	277	319	376	1245	1210	2440	3480	73.6	60.9		
359	85	64	39	31	20	14	---	2	---	---	18	62	20	2.59	38.3	3.3	274	357	319	376	2140	3680	---	---	95.1	---		
360	87	69	48	27	17	10	7	4	2	---	23	60	17	2.66	31.1	2.9	250	338	318	374	955	1392	1652	1947	90.3	71.6		
361	58	40	27	12	6	3	2	1	---	---	60	34	6	2.60	39.1	3.4	174	282	351	392	1671	3148	2283	2732	72.1	115.1		

362	91	72	45	25	14	8	4	2	1	18	68	14	2.70	44.9	2.4	199	281	251	370	1224	2633	1811	2762	75.8	95.3
363	99	50	90	50	20	5	3	1	---	---	80	20	2.88	40.7	1.5	156	247	267	388	583	997	2004	2491	63.7	40.1
364	100	97	54	18	7	4	2	1	---	2	91	7	2.73	40.1	1.6	247	392	269	388	1209	2408	1555	2598	102.1	92.7
365	92	65	38	22	13	6	3	2	---	20	67	13	2.68	41.1	2.5	272	382	276	373	1530	2510	1795	2499	102.5	100.5
366	76	47	28	17	11	7	4	3	2	43	46	11	2.67	32.4	4.1	203	417	280	375	2196	3685	2005	2323	111.1	158.5
367	96	74	27	4	2	0.5	---	---	---	11	87	2	2.70	36.8	1.7	225	311	255	390	1448	2172	1756	2688	79.7	80.7
368	73	32	11	7	5	1	---	---	---	47	48	5	2.65	39.7	2.1	184	273	216	365	1250	3010	1570	2748	77.1	109.1
369	96	78	57	41	28	16	11	7	2	13	59	28	2.75	34.6	2.9	210	298	330	423	1493	2052	1660	2211	70.4	93.1
370	98	60	25	10	5	3	2	1	1	24	71	5	2.67	39.6	2.5	246	356	228	361	1506	3008	1592	2068	98.8	145.1
371	90	66	34	17	9	4	3	2	---	22	69	9	2.51	40.7	2.3	149	241	251	380	1266	2378	1228	3206	63.5	74.1
372	84	51	28	16	10	7	4	3	2	33	57	10	2.70	39.2	3.1	132	238	241	335	1014	2054	1406	2282	71.1	90.1
373	97	72	46	28	20	10	2	1	---	17	63	20	2.67	33.5	2.6	157	430	263	309	1176	1679	1279	2115	139.1	79.5
374	96	83	57	38	17	8	3	2	---	12	71	17	2.68	38.2	2.2	288	403	288	386	1964	2069	2303	2312	105.2	89.5
375	98	84	50	25	8	4	2	---	---	6	86	8	2.83	37.3	1.8	---	---	---	---	---	3773	3120	---	121.1	---
376	84	55	15	8	4	3	2	---	---	36	60	4	2.63	35.9	2.9	---	---	---	---	---	2870	2918	---	98.5	---
377	88	64	25	12	6	3	2	1	---	27	67	6	2.75	31.9	2.2	290	436	299	380	1700	3127	1593	2679	114.8	111.6
378	99	90	50	22	7	3	2	1	---	2	91	7	2.72	33.3	1.7	215	274	322	365	1325	1959	1593	2679	75.1	73.2
379	96	66	33	18	12	6	3	2	---	22	66	12	2.79	31.9	2.5	255	380	263	309	923	1234	1176	1679	123.1	73.6
380	88	66	33	14	7	4	3	2	2	24	69	7	2.62	38.7	2.1	255	375	277	364	1658	2675	1517	2928	103.1	91.5
381	94	67	23	7	3	2	1	1	---	18	79	3	2.55	33.6	1.7	143	184	206	321	590	1406	1382	2590	57.3	54.3
382	97	87	68	47	31	16	9	7	2	7	62	31	2.66	38.1	2.3	201	311	248	401	1542	2633	1795	2745	77.7	95.6

† Proportion of mortar mixture by volume 1 : 3.

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels.*

[Two test specimens were prepared from each sample of gravel.]

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
1	Albay	Camalig	Cabaran River		Guinobatan-Jovellar Bridge.	Pesos.	119543	Dec. 7, 1914	Vesicular andesite.
2	Do.	Daraga	Yawa River		Albay High School.		149636	Jan. 4, 1924	Andesite.
3	Do.	Oas	Quinal River		Oas School building.		157381	June 9, 1925	Diorite, andesite, and basalt.
4	Do.	Polangui	Polangui River		Boraguit Bridge.		145625	Feb. 3, 1923	Basalt.
5	Antique	Sibalom	Tipuluan River	A	Sibalom-San José irrigation project.	1.00	151651	May 16, 1924	Basalt and andesite.
6	Bataan	Balanga	Talisay River		Balanga Elementary School.		158268	July 31, 1925	Andesite and diorite.
7	Do.	Orani	Orani River		Orani market.		144545	Nov. 11, 1922	Diorite.
8	Do.	Orion	Pandan River		Arellano Memorial School.		147805	June 16, 1923	
9	Do.	Sisiman	Sisiman quarry	A	Cañacao U. S. Naval Hospital.		158945	Sept. 15, 1925	Andesite.
10	Benguet	Baguio	Government Center.		Baguio public works projects.		150865	Mar. 26, 1924	Silicious.
11	Do.	do.	Engineers hill.		do.		150865	do.	Silicious cherty.
12	Do.	do.	City quarry.		do.		150865	do.	Limestone.
13	Bohol	Calape	Creek, barrio Sojoton.		Calape water reservoir.		157389	July 16, 1925	Diorite and limestone.
14	Do.	Dauis	Dauis field.		Dauis Bridge.		146941	May 19, 1923	Limestone.
15	Do.	do.	Punta Cruz beach, Maribohoc.		do.		148043	Aug. 18, 1923	Hard limestone.

	Do.	Jetafe.	Brook, barrio Salog.		Jetafe municipal building.		152175	Jan. 23, 1925	Weathered basalt.
16	Do.	do.	do.		do.		152175	do.	Do.
17	Do.	Loay.	Beach, kilometer 25.		Loboc water reservoir.		157256	May 28, 1925	Coralline.
18	Do.	do.	do.		do.		157256	do.	Do.
19	Do.	Maribahoc.	Punta Cruz beach,		Provincial Trade		155541	Feb. 21, 1924	Do.
20	Do.	do.	kilometers 14-22.		School.				
21	Do.	Valencia.	Seashore at Valencia.		Barrio school.		149876	Jan. 14, 1924	Limestone gravel.
22	Bulacan.	Angat.	Angat River.	U	Angat River dam.		142812	June 3, 1922	Andesite.
23	Do.	Baliuag.	Angat River at Baliuag.	U	Angat River irrigation project.		110912	Dec. 26, 1912	
24	Do.	Bocaue.	Bocaue River.	U	Pullian market.		121142A	Oct. 12, 1915	Altered basalt.
25	Do.	do.	do.	U	Legislative Building, Manila.		145640A	Feb. 5, 1923	Angular andesite.
26	Do.	do.	do.	U	do.		145640B	do.	Do.
27	Do.	do.	do.	U	do.		145640C	do.	Do.
28	Do.	do.	do.	U	do.		145640D	do.	Do.
29	Do.	do.	do.	U	Angat canal structures.		147909	Aug. 2, 1923	
30	Do.	Bustos.	Angat River.	U	Angat River irrigation project.		142997	June 21, 1922	
31	Do.	Hagonoy.		U	Hagonoy market.		110032	Nov. 23, 1912	Slightly weathered andesite.
32	Do.	Malolos.		U	Malolos Trade School.		62645	Nov. 25, 1908	
33	Do.	do.		U	Malolos waterworks.		144590	Nov. 15, 1922	
34	Do.	Pullian.	Pullian River.	U	Pullian market.		121142B	Oct. 12, 1915	Basalt.
35	Do.	do.	do.	U	Santa Ana School (Pampanga).		149972	Jan. 31, 1924	Basalt and andesite.
36	Do.	San Ildefonso.	Ma-asim River.		Angat River irrigation works.		110874	Dec. 25, 1912	
37	Do.	Santa Maria.	Santa Maria River.		Santa Maria River Bridge.		125490	Oct. 13, 1917	Weathered volcanic.
38	Do.	San Miguel.	San Miguel River.		Bolo River Bridge.		113991A	Apr. 23, 1913	
39	Do.	do.	do.		San Miguel Bridge.		147909	Aug. 2, 1923	Andesite and quartz.
40	Do.	do.	At Sibul.		Bolo River Bridge.		113991B	Apr. 23, 1913	

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels—Continued.*

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
41	Cagayan.	Aparri.	Cagayan River		Aparri shore protection.	Pesos.	151294	Apr. 23, 1924	Andesite.
42	Do.	do.	Magapit hills		do.		150665	Mar. 15, 1924	Limestone.
43	Capiz.	Capiz.	Barrio Tanza quarry		Bainica River Bridge		150602	Feb. 26, 1925	Andesite and basalt.
44	Do.	do.	Kilometer 9, Capiz-Paintan road.		Capiz Elementary School.		153395	Oct. 14, 1925	Diorite.
45	Cavite.	Cavite.	Rio Grande		General Trias School.		123520	Nov. 15, 1916	Volcanic.
46	Do.	General Trias.	Malabon River		do.		151028	Apr. 5, 1924	Hard basaltic.
47	Do.	Imus.	Imus River		do.		123446	Nov. 1, 1916	Vesicular basalt.
48	Do.	Kawit.	do.		Aguinaldo School		122313A	Apr. 28, 1916	Basalt and andesite.
49	Do.	do.	Rio Grande		do.		122313B	do.	Basalt and volcanic.
50	Do.	do.	do.		Calero River Bridge.		123444	Nov. 1, 1926	Weathered volcanic.
51	Do.	Noveleta.	San Juan River.		Kawit-Noveleta road.		81888	Sept. 6, 1910	Volcanic.
52	Do.	do.	Rio Grande		Noveleta-Cavite road.		123306	Oct. 6, 1916	Weathered scoriaeous basalt.
53	Do.	do.	San Juan River at bridge.		do.		125976	Jan. 2, 1918	Hard vesicular basalt.
54	Do.	do.	Barrio Bacao		do.		125976	do.	Coralline.
55	Cebu.	Barili.	Barrio Guibuañgan		Barili School.		152600	July 24, 1924	Hard limestone.
56	Do.	Carcar.	Open field out of town.		Carcar waterworks.		147128	June 2, 1923	Basalt and silicious limestone.
57	Do.	Cebu.	Buhisan Creek		Osmefa waterworks.	1.50	152215	June 26, 1924	Diorite, andesite, and limestone.
58	Do.	do.	do.		do.		154355	Dec. 4, 1924	Decayed volcanic.
59	Do.	do.	Guadalupe River		Cebu Normal School.	2.25	144670	Nov. 20, 1922	Weathered diorite.
60	Do.	do.	do.		do.	2.25	145779	Feb. 17, 1923	

61	Do	do	Mananga River	do	Mananga River	78560A	May 16, 1910		
62	Do	Danao	Danao River	do	Danao River	78560B	do		Silicious limestone.
63	Do	do	Rock quarry	do	Rock quarry	81168A	Sept. 14, 1910		
64	Do	Dumanjug	River at Dumanjug	do	River at Dumanjug	144887	Dec. 4, 1922	2.50	Rounded limestone.
65	Do	Santander	Santander beach	do	Santander beach	156086	Mar. 19, 1925		Coralline.
66	Do	Talisay	Mananga River	do	Mananga River	81168B	Sept. 13, 1910		Basalt and andesite.
67	Do	Toledo	Tajao River	do	Tajao River	122395	May 12, 1916		Basalt and corals.
68	Iloos Norte	Laoag	Laoag River	do	Laoag River	149320	Dec. 6, 1923		Basalt and andesite.
69	Do	do	do	do	do	121023	Sept. 22, 1915		Andesite.
70	Iloos Sur	Candon	Santa Cruz River	do	Santa Cruz River	kl51979	June 10, 1924		Do.
71	Do	Vigan	Govantes River	do	Govantes River	151380	Apr. 25, 1924		Andesite and diorite.
72	Do	do	Mestizo River	do	Mestizo River	151380	do		Do.
73	Iloilo	Oton	do	do	do	88922A	June 14, 1911		
74	Do	Santa Barbara	Santa Barbara River	do	Santa Barbara River	88922B	do		
75	Do	do	do	do	do	121659	Dec. 29, 1915		Basalt and quartz.
76	Do	do	Tigum River	do	Tigum River	137630	Feb. 17, 1921		Diorite and limestone.
77	Do	do	Santa Barbara River	do	Santa Barbara River	154416	Dec. 8, 1924		Basalt andesite and trachyte.
78	Do	do	Santa Barbara Pit	do	Santa Barbara Pit	155601	Feb. 25, 1924		Basalt and andesite.
79	Do	San Miguel	Aganao River	do	Aganao River	142720	May 25, 1922		Sandstone, andesite, and quartz.
80	Do	do	do	do	do	144036	Oct. 3, 1922		
81	Do	do	Oton beach	do	Oton beach	145778	Feb. 17, 1923		Andesite and diorite.
82	Laguna	Los Baños	Quarry, lower ledge	do	Quarry, lower ledge	83395A	Oct. 17, 1910		Basalt.
83	Do	do	Quarry, upper ledge	do	Quarry, upper ledge	83395B	do		Do.
84	Do	do	Quarry, lower ledge	do	Quarry, lower ledge	83395C	do		Do.
85	Do	Majayjay	Majayjay River	do	Majayjay River	132070	Dec. 6, 1919		Andesite and trachyte.

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels—Continued.*

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available, A, abundant; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter at the job site.	Laboratory No.	Date sample was received.	Mineralogic classification.
86	Do.	do.	Majayjay rock quarry.		do.	Pesos.	132071	do.	Worn andesite.
87	Do.	do.	Olla River stone.		Majayjay market.		158670	Aug. 27, 1925	Andesite and diorite porphyry.
88	Do.	Pagsanjan	Pagsanjan River, hand picked.		Pagsanjan waterworks		128904	Dec. 6, 1918	Vesicular basalt and andesite.
89	Do.	Rizal	Paac River.		Rizal School.		145191	Dec. 27, 1922	Basalt.
90	Do.	Santa Cruz	Santa Cruz River.		Santa Cruz Hospital.		149828	Jan. 21, 1924	Andesite.
91	Leyte	Barugo	Balughay River		Barugo School.		121025	Sept. 22, 1915	Diorite, slightly weathered.
92	Do.	Carigara.	Punong River.		Carigara School.		145325	Jan. 8, 1923	Weathered diorite and andesite.
93	Do.	Ormoc.	Anilao River.		Ormoc market.		159885	Nov. 11, 1925	Diorite.
94	Do.	Tacloban.	Tigbao River.		Tacloban wharf.		145557	Jan. 26, 1923	Andesite, highly weathered.
95	Do.	do.	Punta Anibong		do.		150160	Feb. 12, 1924	Diorite.
96	Marinduque.	Boac.	River bed at Boac.		Boac pier.	3.00	155970	Mar. 17, 1925	Andesite and basalt.
97	Do.	Gasan.	Gasan seashore.		M a t a n d a g Asan Bridge.		151127	Apr. 11, 1924	Andesite.
98	Masbate.	Masbate.	Togbo River.		Masbate market building.		152784	Aug. 7, 1924	Andesite and basalt.
99	Mindanao.	Cagayan (Misamis).	Cagayan River.		Cagayan wharf.		125044A	Mar. 10, 1916	Basalt and andesite.
100	Do.	do.	Cagayan beach.		do.		125044B	do.	Do.

101	Do.	do.	Cagayan River.	Cagayan Central School.	123102	Aug. 24, 1916	Volcanic scoria.
102	Do.	Cotabato (Cotabato).	Limapatoy River	Cotabato Hospital.	121500	Nov. 30, 1915	Porous coralline.
103	Do.	do.	Rio Grande.	do.	147912	Aug. 2, 1923	Limestone.
104	Do.	Davao (Davao).	Davao River.	Davao wharf.	157984	Aug. 20, 1925	Basalt andesite.
105	Do.	do.	do.	do.	157984	do.	Do.
106	Do.	Jolo (Sulu).	Zamboanga River.	Jolo public works.	118287	Feb. 21, 1914	Coralline.
107	Do.	do.	do.	Jolo wharf.	147514	July 2, 1923	Hard andesite.
108	Do.	do.	Crushed rock from ledge.	do.	154787	Jan. 6, 1925	Gneiss, basalt, and vesicular lava.
109	Do.	Surigao (Surigao).	Beach, Bilar point.	High School building	152657	July 29, 1924	Andesite and diorite.
110	Do.	Zamboanga.	Baliwasan beach.	Zamboanga wharf.	156544	Apr. 16, 1925	Vesicular basalt and some limestone.
111	Do.	do.	do.	do.	156544	do.	Do.
112	Do.	do.	do.	do.	156545	do.	Andesite, basalt, and corals.
113	Do.	do.	do.	do.	156545	do.	Do.
114	Nueva Ecija	Cabanatuan	Rio Grande	Provincial Hospital	150668	Mar. 15, 1924	
115	Do.	Caranglan	River at Caranglan	Kabolinpanan Bridge.	147349	June 19, 1923	
116	Occidental Negros.	Bacolod	Lupit River	Provincial Hospital	156702	Apr. 27, 1925	Andesite, basalt, and diorite.
117	Do.	Bago.	Bago River	Bago School.	151985	June 10, 1924	Andesite and diorite.
118	Do.	Cadiz	Talabaan River.	Cadiz municipal market.	158884	Sept. 10, 1925	Andesite.
119	Do.	La Castellana.	Bungahin River.	La Castellana municipal building.	158982	Sept. 17, 1925	Andesite and diorite.
120	Do.	Mao (Bago).	Maragandang River.	Mao School.	150747	Mar. 19, 1924	Andesite.
121	Do.	Pulupandan.	Bago River.	Pulupandan wharf.	158272	July 31, 1925	Andesite, basalt, and diorite.
122	Do.	Talisay.	Matabang River.	Talisay School.	151003	Apr. 3, 1924	Diorite.
123	Do.	Isabela.	Binalagan River.	Isabela School.	153664	Oct. 16, 1924	Andesite and diorite.

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels—Continued.*

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter at the job site	Laboratory No.	Date: sample was received.	Mineralogic classification.
124	Oriental Negros.	Amblan	Amblan River.		Bureau of Public Works project H. H. 44.	Pesos.	79103	June 18, 1910	
125	Do	Bais	Bais River.		Bais River Bridge.		122047A	Mar. 10, 1916	Weathered basalt.
126	Do	do	do		do		122047B	do	Do.
127	Do	Dumaguete	Bainica River.		Storage tank.		145641	Feb. 5, 1923	Vesicular basalt and hard gabbro.
128	Do	Tanhay	Tanhay River.		Bureau of Public Works H. H. 44.		79103	June 18, 1910	
129	Palawan	Coron	Banga River.		Coron wharf.		155108	Jan. 23, 1925	Ferruginous chert and weathered feldspar.
130	Do	do	Coron beach		do		124027	Feb. 8, 1917	Iron-stained quartz.
131	Pampanga	Angeles	Abacan River.		Angeles Bridge No. 89.		146672	Apr. 25, 1923	Diorite.
132	Do	do	do		Angeles Bridge.		147418	June 22, 1923	
133	Do	Magalang	Paitan River.		Magalang municipal building.		146670	Apr. 25, 1923	Scoriaceous basalt.
134	Rizal	Binangonan	Angono River.		Angono Bridge.		121842	Feb. 3, 1916	Basalt.
135	Do	do	Talim Island quarry		Passay concrete road.		149665	Jan. 8, 1924	Do.
136	Do	do	do		do		149776	Jan. 17, 1924	Basalt.
137	Do	do	do		Legislative building.		152782	Aug. 17, 1924	Do.
138	Do	Malabon	Tinajero River.		Legislative building.		150919	Mar. 29, 1924	Basalt and andesite.
139	Do	do	do	A	do		152146A	June 20, 1924	Andesite and basalt.
140	Do	do	Talim Island quarry	A	do		152146B	do	Basalt.
141	Do	McKinley	Pasig River.	A	do		152146C	do	Andesite and basalt.
142	Do	do	do	A	do		151599	May 14, 1924	Andesite and quartz.

143	Do.....do.....do.....				Jones Bridge subway.....	151983	June 10, 1924	Andesite and a few shells.
144	Do.....Pasig.....				University of the Philippines engineering laboratory.	147904	Aug. 2, 1923	Slightly weathered basalt.
145	Do.....do.....do.....				University of the Philippines chemical laboratory.	149465	Dec. 18, 1923	Basalt and andesite.
146	Do.....do.....do.....			A	University of the Philippines High School.	149997	Feb. 1, 1924	Basalt.
147	Do.....do.....do.....			A	Jones Bridge.....	152274	June 23, 1924	Andesite and basalt.
148	Do.....San Juan.....				Legislative building.....	154013A	Nov. 11, 1924	Andesite and basalt.
149	Do.....do.....do.....				do.....do.....	154013B	do.....do.....	Weathered diorite.
150	Do.....do.....do.....				Philippine General Hospital.	154014	do.....do.....	Dark brown diorite.
151	Samar.....				Borongan Bridge.....	150107A	Feb. 8, 1924	Andesite.
152	Do.....do.....do.....				do.....do.....	150107B	do.....do.....	Do.
153	Do.....do.....do.....				Borongan public buildings.	151147A	Apr. 12, 1924	Do.
154	Do.....do.....do.....				Bato River at Canabong.	151147B	do.....do.....	Do.
155	Do.....Calbayog.....				Calbayog municipal building.	154084	Nov. 14, 1924	Andesite porphyry.
156	Do.....do.....do.....				do.....do.....	154084	do.....do.....	Diorite.
157	Do.....Catarman.....				Catarman market.....	151087	Apr. 9, 1924	Slightly weathered andesite.
158	Do.....Llorente.....				Llorente School Building.	152723	Aug. 4, 1924	Andesite.
159	Do.....do.....do.....				do.....do.....	152724	do.....do.....	Do.
160	Do.....do.....do.....			A	Llorente River (Payaan).	152725	do.....do.....	Do.
					Llorente River (Agus)			

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels—Continued.*

Tracing No.	Province.	Municipality.	Location of deposit.	Estimated quantity available. A, abundant; U, unlimited.	For use in the construction of—	Estimated cost per cubic meter at the job site. <i>Pesos.</i>	Laboratory No.	Date sample was received.	Mineralogic classification.
161	Sorsogon.	Bulan.	San Ramon River.		Bulan market.		160424	Dec. 23, 1925	Slightly weathered andesite and basalt.
162	Do.	Castilla.	Kumadkad River.	U	Kumadkad Bridge.		159121	Sept. 25, 1925	Andesite.
163	Do.	Donsol.	Donsol River.		Market building.		14,546	July 5, 1923	Do.
164	Do.	Gubat.	Sagorog River.	U	Sagorog River Bridge.	2.50	150245	Feb. 16, 1924	Hard andesite.
165	Do.	Juban.	Juban River.	U	Juban School building.	2.50	150555	Mar. 7, 1924	Do.
166	Tarlac.	San Miguel.	Cutcut River.		O'Donnell irrigation project.		158313	Aug. 4, 1925	Quartz, diorite.
167	Do.	do.	O'Donnell River.		do.		160176	Dec. 3, 1925	Diorite.
168	Tayabas.	Candelaria.	Cuyapo River.		Candelaria waterworks.		156805	May 4, 1925	Andesite and basalt.
169	Do.	Lucena.	Dumacaa River.		Hospital building.		149687	Jan. 10, 1924	Do.
170	Do.	Tayabas.	Alitao River.		Tayabas market.		152467	July 14, 1924	Basalt diorite.
171	Do.	Tiang.	Gugulman River.		Tiang waterworks.		156806	May 4, 1925	Andesite and basalt.
172	Zambales.	Alhambra.	At source of Uacon River.		Lucapon Bridge.		123121	Aug. 28, 1916	Volcanic.
173	Do.	Cabañgan.	Cabañgan River.		Iba-Subic Road Bridge.		121639	Nov. 23, 1915	Metamorphic.
174	Do.	Candelaria.	Gala-gala beach.		Candelaria School building.		123120	Aug. 28, 1916	Volcanic.
175	Do.	do.	Lauis River.	U	Gamot River Bridge.	3.33	122529	June 5, 1916	Do.
176	Do.	Santa Cruz.	Bayto River.	U	Santa Cruz School building.	4.00	146668	Apr. 25, 1923	Hard andesite.
177	Do.	do.	Perpetuo River.	U	do.		145823	Feb. 21, 1923	Weathered basalt.
178	Do.	San Marcelino.	Santo Tomas River at Santa Fé.		Santo Tomas irrigation project.	2.50	153275	Sept. 15, 1924	Andesite.

Track- ing No.	Mechanical analysis, Per cent passing through screens (circular openings).										Specific gravity of voids.	Sand used with gravel or stone. Labora- tory No.	Compressive strength in pounds per square inch at the age of 28 days.		Mode of failure. M., mor- tar. M. G., mortar- gravel. M. S., mortar- stone.		
													Initial crack.	Ultimate.			
	3.00"	2.25"	1.50"	1.00"	0.67"	0.45"	0.30"	0.20"	0.15"								
1	100	83	66	46	23	6	1	0.4		2.25	27.1	119543	1977	2210			
2		100	81	42	12	2						149637	2502	3290	3430	M. G.	
3		100	98	73	39	10	2.3	0.35	0.3			157382	2082	2547	2451	M. G.	
4		100	32		8		0.7					145626	1900	2539			
5	100	98	51	12	1							151652	1231	1607	1539	M.	
6		100	75	39	9.8	0.7						158269	3914	4234	4250	M. G.	
7												144546	1010	1095	1888	M.	
8												147304	a 1112	b 1187	a 1952	M. G.	
9										2.67		(^c)	1954	2050	2673	2729	M. S.
10	100	100	99	41	9	3	1					150866B	686	754	1069	1119	M.
11			100	86	48	17	6					150866A	1640	1694	2122	2099	M. G.
12			100	98	68	25	13					- do -	1780	1916	2226	2275	M. G.
13		100	91	18	0.5							157988			1060	1108	M.
14	100	98	26	0.3								146940	1846	1433	2400	2356	
15	100	96	53	7	0.2							146940	1002	1034	1372	1532	M. G.
16		100	92	71	31	7	6	5	4			152172A	1620	1560	1680	1678	M.
17		100	92	71	31	7	6	5	4			152172B	1800	1838	2116	2243	M. G.
18		100	85	13	1.3	0.3						157257A	1954	2319	2988	3176	M. G.
19		100	85	13	1.3	0.3	6	5	4			157257B	1353	1532	1518	1569	M. G.
20		100	91	49	6	0.6						155542	2478	2243	2829	2685	M. G.
21		100	78	14	8							149877	1011	1057	1404	1392	M.
22		100	81	12	0.5							142811	1074	1010	2434	2673	M.
23												110874	2055	2282			
24	100	77	50	30	26		0.4			2.62	38.1	121142A	2017	2506	2017	2506	c Ottawa sand.

c Ottawa sand.

b Sand No. 147804C.

a Sand No. 147804B.

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels—Continued.*

Tracing No.	Mechanical analysis. Per cent passing through screens (circular openings).										Specific gravity of solids.	Per centage of voids.	Sand used with gravel or stone. Laboratory No.	Compressive strength in pounds per square inch at the age of 28 days.			Mode of failure. M., mortar; M. G., mortar-gravel; M. S., mortar-stone.
	3. 00"	2. 25"	1. 50"	1. 00"	0. 67"	0. 45"	0. 30"	0. 20"	0. 15"	Initial crack.				Ultimate.			
25			100	99	87	57	39	24	16			145643	859	1774		M. G.	
26		100	99	78	46	18	6	1				145643	820	1650		M. G.	
27		100	89	60	30	7	2	0.4	0.2			145643	868	1885		M. G.	
28		100	96	83	62	30	17	8	5			145643	1004	1798		M. G.	
29		100	97	90	82	62	45	22				149420	1260	1645	1670	M.	
30			100	83	65	41	25	12	7	2.45		142996	1445	1466	2120	2195	M.
31				100	81			40		2.71		110032	(^d)	(^d)	(^d)	(^d)	
32												62645		1180			
33												144591	1022	998	1227	1236	M.
34		100	83	40	18	0.2				2.70		121142C	2246	2929	2429	2929	
35			100	99	95	79	57					• 149486	1112	1280	1280	1676	M.
36												110874	1986	1820	2102	1976	
37		100	83	53	27	5	0.5			2.64		125491	1460	1222	1460	1222	M.
38			100	96	89	67	43	2	1	2.42		113991	1472	1680	1594	1720	
39		100	97	66	31	6	0.4					147908	1784	1760	2337	2541	
40			100	71	57	37	22	11	10	2.45		113991	1611		1699		
41		100	76	35	16	14	11	2				151295	903	916	1007	1113	M.
42			100	93	21	8	1					150666	991	1023	1146	1229	
43		100	87	29	5.5	0.1						• 155603	2150	2158	2527	2578	M. S.
44	100	98	76	15	2	0.5	0.1					• 159394	2558	2528	3243	3291	M. S.
45	100	99	64	51	40	24	11	2	1	2.44		123521	785	1037	1531		
46		100	90	48	12	1						151029	1389		1531		
47		100	73	70	62	51	42	25	3	2.10		123445	785		1038		
48			100	90	78	63	46	27	8	2.35		122314A	881		1588		

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels—Continued.*

Trace- ing No.	Mechanical analysis. Per cent passing through screens (circular openings).										Specific gravity of voids.	Sand used with gravel or stone. Laboratory No.	Compressive strength in pounds per square inch at the age of 28 days.				Mode of failure. M., mor- tar- gravel. M. S., mortar- stone.
	3. 00"	2. 25"	1. 50"	1. 00"	0. 67"	0. 45"	0. 30"	0. 20"	0. 15"	Initial crack.			Ultimate.				
78		100	80	32	11	1.3	0.1				155603	2183	2151	2558	2411	M. G.	
79		100	89	65	48	27	16	8	5	2.56	142721	1000	830	1665	1296	M. G.	
80		100	96	84	68	40	22	10	5		144037	1456		1977		M. G.	
81		100	85	62	44	17	5	0.2			145780	856		1531		M.	
82			100	22	6	2	0.3			2.58	86085A	1328	1611	2078	1945	M.	
83			100	16	2	0.1				2.58	86085C		1347		1528	M. G.	
84			100	16	2	0.1				2.58	86085B	1450	1000	1728	1647	M. G.	
85			100	94	70	46	23	14	8	2.41	132068	2045	2012	2636	2778	M. G.	
86	100	88	38	4	2					2.37	132068	2222	2347	3098	3245	M. S.	
87	100	98	44	3							158671	1636	1555	2290	2170	M. G.	
88										2.28	128903	1636	1555	2290	2170	M. G.	
89			100	67	32	1					145733	1591		3260		M. G.	
90			88	50	26	8	2	1			149829	2155	2311	3098	3027	M. G.	
91	100	88	59	42	14	0.2				2.31	121025	1387	1925	1895	2155	M. G.	
92		100	94	14	0.5	0.1				2.42	145326	350	275	1416	1673	M. G.	
93		100	64	17	3.5	0.2				2.40	159886	1808	1751	2449	2443	M. G.	
94		100	97	90	75	43	29	15	6		121583	1125		1223		M. G.	
95	100	83	33	5	1						150161A	1215	1120	1634	1584	M. G.	
96		100	92	66	42	19	5.6	0.15	0.05		155971	1629	1634	1744	1771	M. G.	
97			100	89	46	8	1				151128	1327	541	1612	680	M.	
98	100	97	62	27	9	1	0.2				152783	1560	1690	2065	2181	M. G.	
99			100	98	98	62	40	18	12	2.61							
100				100	33	3	0			2.62							

Proportion of concrete mixture 1 : 2.5 : 5.

Proportion of concrete mixture 1 : 2 : 5.

r Proportion of concrete mixture 1 : 2.5 : 5.

o Proportion of concrete mixture 1 : 2 : 5.

TABLE 9.—*Mechanical analysis and compressive strengths of Philippine gravels—Continued.*

Tracing No.	Mechanical analysis.										Specific gravity.	Per-centage of voids.	Sand used with gravel or stone. Laboratory No.	Compressive strength in pounds per square inch at the age of 28 days.			Mode of failure. M. mortar. M. G. gravel. M. S. mortar-stone.
	Per cent passing through screens (circular openings).													Ultimate.			
	3. 00"	2. 25"	1. 50"	1. 00"	0. 67"	0. 45"	0. 30"	0. 20"	0. 15"	Initial crack.							
129	100	98	49	14	1					155109	1392	1383	1469	1453	M. G.		
130									2. 66	124014	1986	2443	2443		M. G.		
131		100	54	2	0.1					146673	1082	2430	2430		M. G.		
132	100	44	5	0.6						147419	1117	1343	2077	2277	M. G.		
133	100	92	64	35	13		3	1		146671	1036	1899	1899		M. G.		
134	100	84	56	45	29		17	4	0.4	121816	* 901	* 1052	* 1356	* 1086	M.		
135	100	99	42	29	28	18	9	4		149666	1894	1470	2400	2456	M. S.		
136	100	94	52	28	23	21	20	20		149777	1861	2400	2456		M. S.		
137	100	87	42	11	1					152145	2185	2066	2952	2834	M.		
138	100	69	32	19	7		3			(?)	1493	1552	1846	1882	M.		
139	100	98	89	62	33	10	4	0.6	0.3	152145	1670	1650	2303	2235	M.*		
140	100	55	5	0.7	0.1					152145	1632	1676	2227	2294	M.*		
141	100	97	86	64	28		12	3	0.4	152145	1598	1170	1900	1374	M.		
142	100	98	82	52	23		12	3	0.3	151600	1342	1311	1506	1452	M.		
143	100	98	91	65	32		12	3		151984	786	773	1260	1241	M.		
144	100	92	76	61	38		22	12	8	(?)	1288	1260	2295	2422	M. G.		
145	100	99	92	73	46	20	10	4		149466	1561	1427	1787	1665	M.		
146	100	92	76	47	20	12	8			(?)	1464	1475	1518	1555	M.		
147	100	91	75	49	21	14	9	7		152173	1780	1866	1833	1975	M. G.		
148	100	97	81	68	44	25	9			154012	1814	1696	1919	1786	M. G.		
149	100	94	87	84	42	16	7	3		154012	2208	2086	2394	2404	M. G.		
150	100	80	47	15	1					153845	1172	1189	1455	1393	M.		
151	100	96	66	28	10	2				150108B	1393	1444	1778	1797	M.		
152	95	77	61	45	18	2				150108A	1444	1617	1854	1991	M.		
153		100	95	85	55	18	2			151148E	1444	1617	1854	1991	M.		

PHYSICAL CHARACTERS OF THE AGGREGATES AS REPORTED IN
TABLES 8 AND 9

ALBAY PROVINCE

The sand specimens from Albay Province are well graded, the coarse and medium particles being well balanced, with a relatively smaller percentage of fine particles. The uniformity coefficient, as well as the specific gravity, is fairly high and indicates the good quality of the sands. They possess good mortar strength, both tensile and compressive.

Few gravel specimens were received from Albay Province; all of them, however, possess good compressive strength, when properly used in concrete with sand from the same locality.

ANTIQUE PROVINCE

There is wide variation in the physical characters of the sands from Antique Province. In general, they are composed of medium-coarse particles; the average specific gravity is fairly high; the uniformity coefficient varies from 1.6 to 6.1. Three samples from Sibalom River are of widely different granulometric composition: No. 151469 is medium-fine sand, No. 151652 is medium sand, and No. 151980 is medium-coarse sand. The first two specimens have low tensile and compressive strengths; the third, however, is very satisfactory. Another poor specimen is that from Timpuluan River, No. 152179B; this is medium sand, has very few coarse particles, and has a low uniformity coefficient. The tensile and compressive strengths of this sand are somewhat low. On the other hand, a coarse sand from Magranca beach (No. 154419), in spite of its low uniformity coefficient (1.8), has shown very high tensile and compressive strengths.

There is only one gravel specimen from Antique Province; it is from Timpuluan River. Its low strength is due to poor grading and to the poor quality of the sand used. Indications are that gravel deposits are found also in the beds of Sibalom River, but they are of inferior quality.

BATAAN PROVINCE

The sands from Bataan Province are composed mainly of medium-coarse particles; they have fairly high specific gravity, and a rather variable uniformity coefficient. In general, they have high tensile and compressive strengths. A medium-fine sand specimen from Mariveles beach, No. 117596, has exceptionally low compressive strength, undoubtedly owing to its high percentage of voids and low uniformity coefficient.

A few gravel specimens were received from Bataan Province. No. 158268, from Talisay River, mixed with the sand from the same locality, has exceptionally high compressive strength; on the other hand, No. 144545, from Orani River, has somewhat low compressive strength, because of the poor quality of the sand used.

BATANGAS PROVINCE

Owing to the volcanic nature of the origin of the sand specimens from Batangas Province, their specific gravity is relatively low; the granulometric composition is fairly variable, but variation in the uniformity coefficients is small. The highest tensile strength registered was 305 pounds and the highest compressive strength was 2,343 pounds per square inch; the average values are very much lower, indicating that the sands from this region are of inferior quality.

Some gravel specimens were received from Batangas Province. The results of the tests, however, were not incorporated in the tables, because reliable data on the location of the deposits were not furnished. Like the sands, they are of inferior quality.

BENGUET SUBPROVINCE

The sand specimens from Benguet Subprovince, with the exception of those from Trinidad, are not natural sands; they are screenings. The medium-coarse natural sand from Trinidad, No. 110110B, showed a tensile strength of 504 pounds against 220 pounds of the medium-fine sand, No. 110110A, from the same place. The coarser stone screenings gave very much higher tensile and compressive strengths than did the finer screenings.

Only crushed stones and no gravel were received from Benguet. The limestone and chert mixed with the screenings from the same rocks gave fairly good compressive strength.

BOHOL PROVINCE

The medium-sized particles predominate in the greater number of the sand specimens from Bohol Province. The specific gravity is fairly high, but the uniformity coefficient is very low. The presence of the medium particles and especially the medium-fine particles in predominating quantities and, to a certain extent, the low uniformity coefficient are no doubt the causes of the low tensile and compressive strengths of the greater number of the Bohol sands. Satisfactory results were obtained with the coarse sands taken from the mouth of Panangatan River, No. 150416B; from Punta Cruz beach, No. 155542; and from

kilometer 25 at Loay, No. 157257A. The medium-coarse sands from the seashores of Tagbilaran, No. 156614, and Umpas, No. 156616, and the medium sands from the seashores of Tanguhay and Duero, Nos. 145398 and 145399, also gave satisfactory results.

Many gravel specimens from Bohol are likewise of low quality; however, the two specimens from Punta Cruz beach, No. 155541, and from kilometer 25 at Loay, No. 157256, showed exceptionally high strength. Some mortar failures should be attributed partly to the poor quality of the sand used and partly to the poor grading of the gravels.

BULACAN PROVINCE

Although the sand specimens from Bulacan Province are mostly composed of medium particles, as a whole they have good tensile and compressive strengths. The specific gravity is fairly high and there is little variation in the uniformity coefficient. Three samples, Nos. 142811, 142996, and 145288C, composed of medium-coarse particles and having a low percentage of voids, are especially mentioned here because of their exceptionally high compressive strength, the three samples showing 4,706, 4,336, and 3,200 pounds per square inch, respectively. These sands were taken from Angat River; the first at Angat, the second at Bustos, and the third at Pulilan. The Bustos sand is well graded, showing a low percentage of voids (21.8), a fairly high uniformity coefficient (3.85), and an exceptionally high tensile strength (518 pounds per square inch), which is far above that of Ottawa sand.

Gravel of good quality from Bulacan Province comes mainly from Angat River. Gravels taken from Bocaue River, with the exception of one, No. 121142B, showed somewhat low compressive strength. However, it is always possible, by mixing this gravel with that from Angat or some other locality in Bulacan Province, to obtain a fairly good concrete material.

CAGAYAN PROVINCE

Few sand specimens were received from Cagayan Province. Unfortunately, none of them has given satisfactory results, no doubt because of the poor granulometric composition of the sand, which is composed mostly of fine particles and medium-fine particles.

Two gravel specimens were received from Cagayan Province, and both showed very low compressive strength.

CAMARINES NORTE PROVINCE

The only sample of sand received from Camarines Norte Province is a medium-coarse quartz sand, possessing a high uniformity coefficient, and exceptionally high tensile and compressive strengths.

No gravel specimen was received from this province.

CAPIZ PROVINCE

The sand specimen from Panay River, No. 121656, and one of the two specimens from the junction of Lauan and Capiz Rivers, No. 121434, have fairly high compressive strength. It is interesting to note the great difference in the compressive strength of the sands from two points of the same river junction, Nos. 121658 and 121434. Their granulometric composition is about the same; both are composed mainly of medium and fine particles; both have practically the same specific gravity; they have the same uniformity coefficient; and there is very slight difference in the percentage of voids. However, the compressive strength of No. 121434 is about 260 per cent of the compressive strength of that of No. 121658. This is possibly due to the quantity of clay, about 5.5 per cent, and a small amount of weathered material contained in No. 121658.

No gravel specimen from Capiz Province was submitted for test. The crushed stones taken from quarries, one located at barrio Tanza, and one at the Capiz-Paintan road, kilometer 9, are of good quality and both possess the strength required for use in concrete construction work.

CAVITE PROVINCE

The sands from Cavite Province, like those from Batangas Province, are characterized by low specific gravity, owing to their volcanic origin. Their granulometric composition is good; they are mainly composed of medium-coarse particles, and a very small proportion of fine particles; the uniformity coefficient is fairly high, but the tensile and compressive strengths are low, with the exception of sample No. 149506, from Noveleta River, which has a compressive strength of 2,220 pounds per square inch.

The gravels, like the sands, are of volcanic origin. With the exception of No. 122313B, from the Rio Grande, the specimens tested are of poor quality for use in concrete work.

CEBU PROVINCE

There is considerable variation in the granulometric composition and uniformity coefficient of the sands from Cebu Province. Most of the specimens are composed of medium-coarse sands, have fairly high compressive strength, and in some cases correspondingly high tensile strength. One sample, from Argao River, No. 147975B, composed almost entirely of coarse screenings, is especially mentioned here, because of its unusually high tensile and compressive strength.

Gravel of good quality is also available in many localities in Cebu. Two samples, one from a limestone quarry at Danao and another from Mananga River, Nos. 81168A and 81168B, mixed with Pasig River sand, showed compressive strengths of 3,183 and 2,797 pounds per square inch, respectively.

ILOCOS NORTE PROVINCE

The few sand specimens from Ilocos Norte Province were taken from Laoag River. They are fairly good, except the specimen taken at the dam site (No. 150853) which, being somewhat weathered, gave low tensile and compressive strengths.

Two gravel specimens were also taken from Laoag River. They possess fairly good strength. Better selection and proper proportioning and grading of the materials will give better results.

ILOCOS SUR PROVINCE

The sands from Ilocos Sur Province are mainly composed of medium-fine particles possessing low uniformity coefficient, and high specific gravity. Indications are that sands of good quality can be secured from Ilocos Sur Province.

The few gravel specimens received from Ilocos Sur Province are of good quality, being mainly composed of hard andesitic fragments. Their low compressive strength is due to the poor quality of the sands used.

ILOILO PROVINCE

The sands from Iloilo Province in general are medium-coarse sands possessing rather variable uniformity coefficient but fairly uniform specific gravity. The tensile and compressive strength at the age of twenty-eight days is also uniformly high, with the exception of the specimen from Jaro River, No. 154417. The Iloilo sands, judged by the results of the test, are quite satisfactory for use on concrete construction work.

The gravels, likewise, possess satisfactory compressive strength, except No. 142720, from Aganao River, which contains 15 per cent clay and silt; No. 145778, from Oton beach, which was tested under special conditions (that is, exposed in the open air for twenty-eight days); and No. 154416, from Santa Barbara River, which failed because of the poor quality of the sand.

LAGUNA PROVINCE

The sands from Laguna Province are composed of medium-coarse particles, and the specific gravity, uniformity coefficient, and the tensile and compressive strengths are very variable. The highest two compressive strengths registered were 4,721 and 4,390 pounds per square inch, corresponding to No. 143644, from Mayton River, and No. 149829, from Santa Cruz River, respectively. Incidentally, these two specimens have also the highest specific gravity, 2.70 and 2.77, respectively. With very few exceptions, the Laguna Province sands can be considered of satisfactory quality for use in concrete work.

The gravels also possess high compressive strength, especially those from Santa Cruz and Olla Rivers. The low results shown by a few specimens were due to the poor sands used. The crushed stone from a Los Baños quarry, No. 83395, is of poor quality.

LEYTE PROVINCE

Most of the Leyte sands are composed of medium-fine particles with very little or practically no coarse particles. Although the specific gravity is fairly high, the tensile and compressive strength is unsatisfactory, owing perhaps to the general low uniformity coefficient and the high percentage of voids of the specimens submitted; as a matter of fact, only seven of twenty-two samples, or about 33 per cent, gave satisfactory results.

Few gravel specimens were received from Leyte Province. With the exception of the sample from Baluguhay River, No. 121025, they show low compressive strength.

MARINDUQUE PROVINCE

The sands from Marinduque Province, although of medium-fine particles, have high specific gravity, and a low percentage of voids; it is for this reason that they have fairly good tensile and compressive strengths, except the fine sand from Matandang River.

Only two gravel specimens were received. Both have low compressive strength.

MASBATE PROVINCE

Few sand specimens were received from Masbate Province. Three are medium sand and one is medium-coarse. The specific gravity is fairly high and the uniformity coefficient slightly variable and fairly good, but the tensile and compressive strengths are relatively low.

Only one gravel sample was received from Masbate Province; it was taken from Tagbo River. It has fair compressive strength, in spite of the relatively low strength of the sand with which it was mixed.

MINDANAO ISLAND

In as much as there are only a few well-organized municipalities in Mindanao, the exact locations of the deposits of the aggregates were not clearly stated on the cards attached to the specimens; for this reason, all the aggregates are here considered under one heading.

The sands were gathered mainly from the seashores and only a few from the rivers. In general, they possess good tensile and compressive strengths. Good sands are not localized in any definite section of the island; they are found in Zamboanga, as well as in Sulu, Cotabato, Davao, and Cagayan. The following specimens have given exceptionally high tensile and compressive strengths: No. 123101, from Cagayan River; No. 154786, from Zamboanga beach; Nos. 156546A and 156546B, from Baliwasan beach; and No. 157985, from Davao River. These sands are characterized by low percentage of voids, fair specific gravity, and the presence of a higher proportion of coarse grains.

The gravels, like the sands, have given very satisfactory compressive strength. Many of the specimens have a breaking strength of 3,000 pounds or more per square inch.

NUEVA ECIJA PROVINCE

Two sand specimens were received from Nueva Ecija Province; one, composed of medium-coarse particles, and the other of coarse particles. Both specimens possess good tensile and compressive strengths.

Also, two gravel specimens were received. Both can be considered of fair quality for use in concrete work.

OCCIDENTAL NEGROS PROVINCE

In general, the sand specimens from Occidental Negros Province may be rated as fair. They are composed mostly of medium particles; the specific gravity, on the whole, is below

the average and, although the percentage of voids is relatively lower, the tensile and compressive strengths are not very satisfactory. However, samples No. 148964, from Alejandra River, and No. 159768, from Bungalin River, have given compressive strengths of 3,260 and 3,509 pounds per square inch, respectively.

The gravels, on the other hand, have good compressive strength. The low results registered were due to mortar failures, owing to the poor quality of the sands used.

ORIENTAL NEGROS PROVINCE

Three sand specimens were received from Oriental Negros Province. Like those of Occidental Negros, they are composed of medium particles. Their specific gravity and tensile and compressive strengths are below the average values for good concrete aggregates.

The gravels, however, have fairly good compressive strength.

PALAWAN PROVINCE

The sands from Palawan Province are mainly composed of medium particles; they have a fairly good uniformity coefficient but low specific gravity, due to the weathered condition of the particles. The percentage of voids is high, with the exception of No. 157987, from Coron beach, at the wharf. The tensile and compressive strengths of this specimen were 352 and 2,405 pounds per square inch, respectively.

The gravel specimen from Coron beach is likewise of good quality, but that from Bonga River is very poor.

PAMPANGA PROVINCE

The sand specimens from Pampanga Province are of medium-fine particles and have fair specific gravity and uniformity coefficient, and a comparatively low percentage of voids. The sands, although lacking in coarse particles, are well graded, and consequently possess good compressive strength.

The few gravel specimens submitted from Pampanga Province are of fair quality and, with the exception of No. 146670, from Paitan River, possess the necessary strength required for concrete work.

PANGASINAN PROVINCE

The sands from Pangasinan Province possess the good qualities of high specific gravity and low percentage of voids. They are composed of medium particles and, in general, have a low uniformity coefficient. It is possibly for this reason that the tensile strength is low, although the greater proportion of

the specimens have good compressive strength. Sands No. 144072, from Agno River, and No. 146985, from Aguilar River, have exceptionally high tensile and compressive strengths. Several other specimens have shown higher strength than the standard sand mortars.

No gravel samples were received from Pangasinan Province. Our records on concrete specimens submitted for test, however, indicate that gravels of good quality are found in the beds of many rivers, such as the Abeloleng, the Anonilintap, the Ma-naog, the San Jacinto, etc.

RIZAL PROVINCE

Perhaps no other sand deposit in the Philippine Islands has been so extensively developed as has that of Pasig River, Rizal Province. Proximity to the City of Manila, where concrete construction work is constantly increasing in volume, is the main cause of this development. Abundant material is available almost any time and prices are reasonable. The materials delivered at the job site cost about 2 pesos and 5 pesos per cubic meter of sand and gravel, respectively.

In general, the sand specimens from Rizal Province are composed of medium-coarse particles; they have fairly good average specific gravity, and a tolerably low percentage of voids. With a few exceptions, the tensile and compressive strengths are very satisfactory; as a matter of fact, in many instances, the Pasig River sand showed higher strength than did standard Ottawa sand.

Pasig River gravel is also of good quality. The low compressive strength registered in the majority of the cases was due to mortar failures. The smooth surface of this gravel, the fact that, oftentimes, it is covered with a film of dirt difficult to remove and, to a certain extent, the poor grading of the materials used in the mixtures are possibly the reasons for the low strength of concrete made from it. In no case has concrete made from this gravel shown the exceptionally high compressive strength that the concrete made from certain specimens from Mindanao and Occidental Negros showed; but, for ordinary purposes, it is a reliable concrete aggregate. Mixtures in the proportion of 1 : 2 : 4 would easily pass the minimum limit of 2,000 pounds per square inch, at the age of twenty-eight days, specified by the Bureau of Public Works.

In this connection, the experience of two practicing engineers of the City of Manila is of interest. In view of the frequent low strength noted in specimens submitted by these engineers for test at the Bureau of Science, they decided to study the cause of the trouble. After several weeks of observation at the site of the work where these materials were being used, they arrived at the conclusion that thorough washing of the materials and conscientious grading of the gravel particles are the necessary requisites to prepare 1 : 2 : 4 concrete cubes that will give a compressive strength of over 2,000 pounds per square inch at the age of twenty-eight days.

To correct the low strength of concrete made of concrete materials from Pasig River, some contractors used, for the coarse aggregate, equal proportions of river gravel and crushed stone from Talim Island. This practice has given very satisfactory results. The gravels taken from Angono, Tinajero, and San Juan Rivers are of similar concrete value as are the Pasig River gravels.

ROMBLON PROVINCE

Few sands were received from Romblon Province; they are of a calcareous nature, either coralline limestone or marble débris. They are medium sands with fairly high specific gravity and rather variable uniformity coefficient. In this particular province, where the specimens are of similar mineralogic classification, those having higher specific gravity, higher uniformity coefficient, and a low percentage of voids also possess higher tensile and compressive strengths.

No gravel or crushed stone specimens were received from Romblon Province. It is safe to assume, however, that crushed marble from marble rocks, which are found in large quantities in this province, will give satisfactory results as concrete aggregates.

SAMAR PROVINCE

The sands from Samar Province are composed mainly of medium-coarse particles, a relatively low percentage of voids, and variable uniformity coefficient and specific gravity. Wide variation is also observed in the tensile and compressive strengths. A coarse-medium sand, No. 119453, from Calbayog beach, has exceptionally high tensile and compressive strengths. This sand has a specific gravity of 2.77. Another medium-

coarse sand, No. 151148B, from Borongan River, gave the lowest tensile and compressive strengths. The specific gravity of the sand is 2.42. There was plenty of clay in the sample.

The gravels from Samar, with the exception of the two specimens from Maylibas River, gave satisfactory compressive strength. All the failures were mortar failures, indicating sand of poor quality or dirty gravel.

SORSOGON PROVINCE

The sand specimens from Sorsogon Province are mainly composed of medium and medium-coarse particles. The variation in the uniformity coefficient is small, but the variation in the specific gravity is noticeable. Although the compressive strength is fairly satisfactory, the tensile strength is low. Sand samples having the highest specific gravity have registered the highest tensile strength, showing once more the close relationship between density and strength.

The gravels from Sorsogon Province are hard dense rocks of good quality for concrete work. The low compressive strength should be attributed partly to the poor granulometric composition of the specimens and partly to the poor quality of the sands used.

SURIGAO PROVINCE

Two sand samples were received from Surigao Province and both have low tensile and compressive strengths. They are medium sands, of low uniformity coefficient and with a high percentage of voids, but with fairly good specific gravity.

No gravel was received from Surigao.

TARLAC PROVINCE

The Tarlac sands are medium-fine sands, possessing fairly good specific gravity, rather variable uniformity coefficient, and a somewhat high percentage of voids. The tensile and compressive strengths, with few exceptions, are generally good. The low strength of the specimens from O'Donnell River is due mainly to the mineralogic character of the sands. Sand No. 123447, from Santiago River, which registered the highest tensile and compressive strengths,⁸¹ possesses all the good properties of a good mortar sand; namely, coarse particles, high

⁸¹ Highest of the 1:3 mixture.

specific gravity, high uniformity coefficient, and low percentage of voids.

Two gravel specimens were received from Tarlac Province, one from Cutcut River, the other from O'Donnell River; they possess exceptionally high compressive strength.

TAYABAS PROVINCE

The granulometric composition of the sands from Tayabas Province is fairly good. These sands are composed mainly of medium particles, but many of the specimens also contain a good proportion of coarse particles. The average specific gravity is high and the uniformity coefficient somewhat variable. The highest tensile and compressive strengths were registered by a medium coarse sand with a low percentage of voids and a high uniformity coefficient. Some specimens showed good compressive strength but low tensile strength.

Few gravel specimens were received from Tayabas Province. They all possessed good compressive strength without gravel failures.

ZAMBALES PROVINCE

The sands from Zambales Province are composed mainly of medium particles, the uniformity coefficient is fairly low, the average specific gravity good, and the percentage of voids fair. They possess better tensile strength than compressive strength. Sands Nos. 123118 and 123119, from sitio Galagala and Lucapon River, respectively, are especially interesting in this respect. The tensile strengths are 123.1 per cent and 139.1 per cent, respectively, of the corresponding tensile strength of the standard Ottawa sand mortar, while the compressive strengths are lower, 73.6 per cent and 79.5 per cent, respectively, of the corresponding compressive strength of the standard Ottawa sand. Judged from the point of view of their tensile strength, the sands are of a superior grade; but, from the results of compressive-strength tests, they are of poor quality for use in concrete work. The two samples are from volcanic rocks, while the rest are andesitic and quartz.

The gravels, in general, possess low compressive strength. Sample No. 153275, from Santo Tomas River, mixed into concrete with sand from the same locality, gave fairly high compressive strength.

SUMMARY AND CONCLUSIONS

Natural deposits of sand and gravel are found in all the provinces of the Philippine Islands.

Sands consisting mainly of medium and fine particles are the most abundant.

Fewer gravel deposits containing large quantities of the material have been located at easily accessible places.

Good aggregates are found in relatively large proportion in Albay, Bulacan, Cebu, Laguna, and Rizal Provinces and on Mindanao Island.

For a given proportion of cement, the mortar and concrete values of hard-grained aggregates depend, to a considerable extent, upon the granulometric composition of the sand and the mechanical analysis of the gravel.

Coarse sand makes stronger mortar than does fine or medium sand. Coarse sand, mixed with well-graded gravel, makes stronger concrete than does coarse sand mixed with poorly graded gravel.

A gravel specimen that contains stones of a maximum size of 3 inches may be considered well graded when not more than 22 per cent will pass through holes 0.67 inch in diameter, and not less than 22 per cent is retained on a sieve with holes 1.5 inches in diameter. Its apparent ideal mechanical analysis graph is a straight line.

ILLUSTRATIONS

TEXT FIGURES

- FIG. 1. Tensile-strength curves computed on the basis of the tensile strength of standard Ottawa sand as 100 per cent.
2. Compressive-strength curves computed on the basis of the compressive strength of standard Ottawa sand as 100 per cent.
 3. Relation between compressive strength and the percentage of coarse, medium, and fine particles, representing the granulometric composition of sands.
 4. Average mechanical analysis curves of gravels used in the testing of concrete specimens, grouped according to their compressive strengths as shown in Table 7.

EFFECT OF CARBON TETRACHLORIDE, CHENOPODIUM, AND THYMOL ON THE OVA OF EXPELLED HOOKWORMS

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The object of this study was to find out whether a drug against hookworm exerts any action on the ova contained in the uteri of expelled female worms. If it can be demonstrated that a vermifuge is capable of inhibiting the development of the larvæ or completely killing the ova even when these are kept under favorable conditions, then such ovicidal action not only may indicate the ancylostomicidal power of the drug but also may possibly be used as an index or coefficient of efficiency.

In a series of observations on hookworms removed from patients and cadavers to determine the maturity and fertility of the females, it was observed that those obtained from autopsy when left in clean tap water at room temperature (25 to 30° C.) for twenty-four hours always, on being crushed between slides, showed motile, free-swimming larvæ, or at least moving, coiled larvæ in the shells, provided the ova had been fertilized.

It was observed that, when the number of parasites was large, almost every female had been fertilized. In only rare cases could an immature or unfertilized female be found.

The present observations were made on female hookworms, removed by treatment, from twenty-five patients. The drugs used in this study were carbon tetrachloride in the dose of 1 cubic centimeter to 7 kilograms and 1 cubic centimeter to 5.5 kilograms of body weight, and without any purgative; chenopodium, 3 cubic centimeters given in 1.5-cubic centimeter doses followed by magnesium sulphate; thymol, 2.6 grams given in 1.3-gram doses followed by magnesium sulphate. All observations were on first treatments, on twenty-four-hour stools, collected and screened (80 meshes to the square inch). Usually half the number of worms were crushed the first twenty-four hours and the other half twenty-four hours later.

Table 1 shows that, in seven patients treated with carbon tetrachloride, a total of one hundred fifty-three female worms

did not show development of active larvæ, either free-swimming or motile in the shell. The ova usually showed swelling and fine granulation with filling up of the shell. In some the shell could hardly be distinguished. Fat globules were frequently seen in the ova.

TABLE 1.—*Worms from patients treated with carbon tetrachloride.*

Patient.	Amount of carbon tetrachloride.	Ancylostoma.		Necator.		Females with larvæ.	Females without larvæ.
		Male.	Female. ^a	Male.	Female.		
	cc.						
1-IC.....	10	0	2	70	68	0	68
4-MP.....	10	0	0	2	3	0	3
7-YK.....	11	0	0	1	4	0	4
8-SM.....	10	0	0	0	3	0	3
9-MC.....	7	6	4	9	17	0	17
VA.....	10.5	1	0	2	5	0	5
DB.....	6.3	2	1	48	53	0	53
Total.....					153		153

^a Not examined.

Table 2 shows that, in ten patients treated with chenopodium, eighty-five female worms showed larval development while three did not, out of eighty-eight worms examined.

TABLE 2. —*Worms from patients treated with chenopodium.*

Patient.	Amount of chenopodium.	Ancylostoma.		Necator.		Females with larvæ.	Females without larvæ.
		Male.	Female.	Male.	Female.		
	cc.						
JM.....	3	2	0	17	13	13	0
TR.....	3	0	0	4	8	8	0
JT.....	3	0	0	3	3	3	0
FS.....	3	0	0	18	24	24	0
EA.....	3	10	1	6	5	6	0
DF.....	3	0	0	6	7	4	3
IT.....	3	0	0	0	1	1	0
DB.....	3	1	0	4	8	8	0
RC.....	3	1	0	6	12	12	0
SP.....	3	0	0	7	6	6	0
Total.....			1		87	85	3

Table 3 shows that, in eight patients treated with thymol, eighty-eight female worms showed active larvæ while eleven did not, out of ninety-nine worms examined.

TABLE 3.—Worms from patients treated with thymol.

Patient.	Amount of thymol.	<i>Ancylostoma</i> .		<i>Necator</i> .		Females with larvæ.	Females without larvæ.
		Male.	Female. ^a	Male.	Female.		
	<i>g.</i>						
JL.....	2.6	0	0	3	14	13	1
JE.....	2.6	0	0	2	5	1	4
MA.....	2.6	1	0	33	35	35	0
P.d.I.R.....	2.6	4	3	9	10	9	1
JB.....	2.6	0	0	10	14	13	1
MB.....	2.6	0	0	13	17	15	2
SV.....	2.6	0	0	0	1	1	0
MG.....	2.6	0	0	5	3	1	2
Total.....					99	88	11

^a Not examined.

Ten female worms in the patients treated with carbon tetrachloride, three in those treated with chenopodium, and eleven in those treated with thymol were found to be without ova (immature) or with ova but showing no division in them (probably mature but not fertilized).

These findings show that carbon tetrachloride as administered is ovicidal, while chenopodium and thymol are not. The observations were mostly on *Necator*, as *Ancylostoma* were few in this series. The findings also seem to confirm the superiority of carbon tetrachloride over the other drugs in this respect.

It may be mentioned here that fifty-six female worms expelled from three adult patients treated with 2 cubic centimeters of tetrachlorethylene did not show larval development except that two female worms contained motile larvæ. One worm from one patient had a free motile larva at the forty-eighth hour after recovery from the stool and another worm from another patient had a coiled moving larva in the shell, also at the forty-eighth hour after recovery.

Thymol was found many times in small lumps in the stool, though it was in very finely powdered form when put into the capsules. In one case two pieces of thymol of the shape of and practically the same size as the capsules administered were encountered in screening the stool. This finding seems very significant, as the frequent failure of this drug may be due to lump formation. It is possible that this may happen not only in the case of solid drugs but also with carbon tetrachloride, the tendency of which is to form globules of varying

sizes in the dependent portion of the container even when thoroughly emulsified. If this could be shown to occur in the intestinal tract (due to failure of peristaltic movements to keep the drug in finely divided form), then the most rational thing to do would be to prepare the drug in such a way as to keep it well separated or emulsified during its journey through the small intestines.

An inert, porous, powdered solid is suggested as a vehicle for anthelmintics, to be triturated with the drug in case it is solid or mixed in the form of paste in the case of a liquid and put up in capsules. The powdered condition of the vehicle, or "carrier," will mechanically prevent fusion of solid drugs. Owing to porosity it will absorb liquid drugs in minute quantities. Charcoal or chalk will probably serve; both are relatively nonirritating, and they do not predispose the mucosa to absorption.

SUMMARY

1. Twenty-five patients were divided into three groups; those of the first group were given carbon tetrachloride in doses of 1 cubic centimeter to every 5.5 kilograms of body weight and 1 cubic centimeter to every 7 kilograms of body weight; those of the second group were given chenopodium, 3 cubic centimeters in two 1.5-cubic centimeter doses, followed by magnesium sulphate; and those of the third group were given thymol, 2.6 grams in two doses of 1.3 grams each, followed by magnesium sulphate.

All stools for twenty-four hours were saved and screened, and the parasites left in separate Petri dishes with tap water at room temperature (25 to 30° C.). They were crushed between slides, some of them twenty-four hours after recovery of parasites and the others the following twenty-four hours.

2. The female parasites expelled by carbon tetrachloride failed to show development of ova into active larvæ, while those expelled by chenopodium and thymol all showed active larval development, except a few, probably immature or unfertilized ones. Mostly *Necator* were examined, as *Ancylostoma duodenale* were few in this series.

3. This ovicidal property of carbon tetrachloride seems to confirm its superiority over chenopodium and thymol in the treat-

ment of ancylostomiasis. Tetrachlorethylene has also been found to be ovicidal.

4. If the results of this study could be confirmed in a larger number of cases, it might be of value in determining the ancylostomicidal coefficient of a drug.

5. Improper emulsification of a vermifuge in the intestine may be responsible for failure.

6. The use of an inert, porous, powdered solid as a vehicle for anthelmintics is suggested.

NEW OR NOTEWORTHY PHILIPPINE BIRDS, V

By RICHARD C. MCGREGOR

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TWO PLATES AND ONE TEXT FIGURE

This paper contains descriptions of two new species of Philippine birds and notes on other species that are of particular interest for one reason or another.¹

MEGAPODIUS CUMINGI Dillwyn.

In May, 1922, Mr. Luis J. Reyes, of the Philippine Bureau of Forestry, left in my office an egg of the tabon with a note that it had been collected near Agloloma, Luzon, on April 7. As the mound builder is not common in Luzon I asked Mr. Reyes for any notes he might have about this bird. On May 16, he sent me the following notes and description of the nesting habits:

Agloloma is a sitio of the Municipality of Mariveles, Bataan, located about seven or eight miles northeast of the town.

Tabon birds are not familiar to me, but I was interested in the description of the manner these birds lay their eggs, as told by the man who collected them. He said that a small flock came one day, and after flying around the place for sometime alighted on the sandy beach. The egg was laid on the surface, and after resting one or two minutes the bird held it on one of its feet and began diving into the sand, using head, wings, and the other foot. He said that while yet near the surface, one could see the sand rise to a considerable height due to the rapid action of its wings. He pointed out to me certain marks on the shell of the egg which he claimed are scratches of the bird's claws. I examined these scratches with a magnifier and I am somewhat convinced that they really are scratches of some kind. He told me also that tabon birds deposit their eggs about a meter deep. The man further told me that once he hatched an egg by burying it deep in unhusked rice. It hatched in about fourteen or fifteen days, and to his surprise, after the newly hatched bird dried its feathers, it flew for a distance of about five meters!

I hope that these notes will be of interest to you. Of course, I cannot vouch for the accuracy of his statements, although I think that the man is fairly reliable.

¹ Part IV of this series was published in *Philip. Journ. Sci.* 19 (1921) 691-703.

GALLICOLUMBA KEAYI (Clarke). Plate 1.

Through the courtesy of Mr. William Parsons, of Manila, I have seen a living male specimen of the Negros puñalada, and Mr. M. Ligaya has made a water-color sketch of it. This bird was sent to Mr. Parsons from San Carlos, Negros, and was in his aviary for some months until made into a skin. The wing, somewhat imperfect, measures 152 millimeters; tail, 100; culmen from base, 22; tarsus, 37; middle toe with claw, 34.

LIMNOBÆNUS FUSCUS (Linnaeus).

G. Taguibao and F. Rivera collected a male on April 9 and a female on April 25, 1923, at Santa Maria, Laguna Province, Luzon.

CHLIDONIAS LEUCOPAREIA (Temminck).

On October 15, 1923, I received from Mr. U. C. Roush, of Tacloban, Leyte, a wing and a leg of a whiskered tern, a species so far unknown from Leyte. This is the species formerly called *Hydrochelidon hybrida* (Pallas).

STERNA SINENSIS Gmelin.

Sterna minuta was recorded from Mindanao by Steere,² and this is cited by Saunders in the synonymy of *Sterna sinensis*.³ Mr. E. H. Taylor collected a male of the white-shafted tern on May 1, 1923, at "Saob" (probably Saub), Cotabato Province, Mindanao, which he presented to the Bureau of Science.

PLUVIALIS FULVUS (Gmelin).

On October 15, 1923, I received from Mr. U. C. Roush, of Tacloban, Leyte, a fresh unstuffed skin of a golden plover. Tweeddale⁴ recorded this species from Leyte on the basis of a pair collected by Everett.

NUMENIUS ARQUATUS (Linnaeus).

A male of the common curlew (Bureau of Science No. 13198) was collected by Andres Celestino near Obando, Bulacan Province, Luzon, on October 12, 1915. I have examined a female of this species that was killed by a hunter in the same region on October 22, 1923.

² Birds and Mammals Collected by the Steere Expedition to the Philippines. Ann Arbor, Mich. (1890) 27.

³ Cat. Birds Brit. Mus. 25 (1896) 114.

⁴ Proc. Zool. Soc. London (1877) 549.

MESOSCOLOPAX MINUTUS (Gould).

Macario Ligaya saw three pygmy curlews in a plowed field near Calamba, Laguna Province, Luzon, and collected a female, on September 24, 1922. Francisco Rivera collected a male and a female, near Baliuag, Bulacan Province, on November 2, 1924.

TOTANUS STAGNATILIS Bechstein.

A male of this long-legged sandpiper was collected by Andres Celestino at Obando, Bulacan Province, Luzon, on January 31, 1926.⁵ Wing, 135 millimeters; tail, 57; exposed culmen, 39; tarsus, 53; middle toe with claw, 31. Stuart Baker⁶ gives the trivial name "marsh sandpiper" to this species. The long slender legs suggest "stilt sandpiper" as appropriate, but that name is in use for *Micropalama himantopus* (Bonaparte), a slightly smaller American species.

ACTITIS HYPOLEUCOS (Linnaeus).

A female example of the common sandpiper was collected on Linapacan Island, between Palawan and Culion, on October 10, 1922, by Andres Celestino. This common species has been recorded from twenty-eight islands of the Philippines and can be expected to occur on many more.

CROCETHIA ALBA (Pallas).

I have examined a male sanderling that was collected by Braulio Barboza at Malabon, near Manila, on March 19, 1905.

CALIDRIS TENUIROSTRIS (Horsfield).

A female of the Asiatic knot was collected by Andres Celestino near Obando, Bulacan Province, Luzon, on January 31, 1926. The wing measures 177 millimeters; tail, 76; exposed culmen, 42; tarsus, 33; middle toe with claw, 30.

CALIDRIS ROGERSI (Mathews).

A female short-billed knot, collected by Andres Celestino near Obando, Bulacan Province, Luzon, on January 31, 1926, is in gray winter plumage. The wing measures 162 millimeters; tail, 65; exposed culmen, 34; tarsus, 31; middle toe with claw, 27. This is the third specimen of this species that we have collected near Obando.

⁵ See Philip. Journ. Sci. § D 11 (1916) 274 and § D 13 (1918) 8 for previous Philippine records of this species.

⁶ Journ. Bombay Nat. Hist. Soc. 28 (1920) 218.

LIMICOLA FALCINELLUS (Pontoppidan).

The first Philippine specimens of the interesting broad-billed sandpiper seem to have been collected in Bohol by Everett, in Palawan by Platen, and in Negros by the Steere Expedition. Later I found it in Cuyo, Cebu, and Luzon. From this it can be seen that the species is well scattered over the Islands when it comes from the north on its way to Australia. Birds of this species are probably more abundant in the fall migration than these few records indicate. Few collectors have paid much attention to Philippine shore and water birds, so that little is known about the occurrence and abundance of such species.

Mathews⁷ uses the name *Limicola falcinellus siberica* (Dresser) for Australian examples of the broad-billed sandpiper, and Philippine birds doubtless belong to that race if it differs from the European one.

We collected this species in Cuyo, January 14 and 15, 1903; at Minglanilla, Cebu, November 23, 1906; and at Obando, Bulacan Province, Luzon, November 15, 1910; October 10, 1915; and February 2, 1925. In January, 1926, for the first time we encountered many birds of this species, and the measurements of fifteen specimens collected at that time are here given.

Measurements of Limicola falcinellus (Pontoppidan) from Obando, Bulacan Province, Luzon.

[Measurements are in millimeters.]

Date.	Sex.	Wing.	Tail.	Exposed culmen.	Tarsus.	Middle toe with claw.
1926						
January 13.....	Male.....	^a 97	35	28	22	21
Do.....	do.....	104	43	31	23	22
Do.....	do.....	105	36	30	20.5	20.5
Do.....	Female.....	103	42	34	22.5	22.5
Do.....	do.....	106	41	35.5	23	23
January 14.....	do.....	105	40	32	22	21
January 16.....	do.....	106	46	36	23	22.5
Do.....	do.....	108	44	36	24	23
Do.....	do.....	106	42	29	22	22
January 31.....	Male.....	102	41	30	22	21
Do.....	do.....	104	44.5	30	22	22
Do.....	Female.....	106	42	33	(b)	20
Do.....	do.....	108	46.5	34	22	22
Do.....	do.....	100	38	29	20	20
Do.....	do.....	111	42	33	23	22

^a Worn.

^b Broken.

⁷ Birds of Australia 3^a (1913) 279, pl. 165.

DUPETOR FLAVICOLLIS (Latham).

Mr. Mauricio Santiago, of Navotas, Rizal Province, Luzon, secured a specimen of the black bittern at Orani, Bataan Province, Luzon, on September 3, 1924. There are few Philippine records of this species.

QUERQUEDULA QUERQUEDULA (Linnæus).

I have examined a male of the Asiatic blue-winged teal that was collected by Braulio Barboza on Laguna de Bay, Luzon, March 12, 1904.

PITHECOPHAGA JEFFERYI Grant. Plate 2.

I have noted the capture of several individuals of this large endemic eagle; but, as is true of other forest-inhabiting Raptores, it is only rarely that this species can be seen. On July 14, 1926, a female monkey-eating eagle was mounted for the owner at the Bureau of Science. It was stated that the bird had been caught, while it was on the ground drenched with rain, near Pagbilao, Tayabas Province, Luzon. The body of the bird was very thin, and the tail feathers were being molted. The weight was 3.02 kilograms. Length, 1,065 millimeters; expanse of wings, 2,000; wing, 590; tail, 600; tarsus, 123; depth of bill at nostril, 53; chord of culmen from cere, 72. The upper mandible has an extremely long overhang. Iris king's blue; bill black, the base light Payne's gray; legs and feet deep colonial buff, nails black; cere and skin about base of bill black.

PHODILINÆ

Photodilinae BLANFORD, Fauna Brit. India, Bds. 3 (1893) 268; SHARPE, Hand-list 1 (1899) 300.

Genus PHODILUS I. Geoffroy Saint-Hilaire

Phodilus I. GEOFFROY SAINT-HILAIRE, Ann. Sci. Nat. 21 (1830) 196-203 (*Strix badia*); SHARPE, Cat. Bds. Brit. Mus. 2 (1875) 309. *Pholidus* HORSFIELD and MOORE, Cat. Bds. Mus. East India Co. 1 (1854) 80 (error).

Photodilus BLANFORD, Fauna Brit. India, Bds. 3 (1895) 268; SHARPE, Hand-list 1 (1899) 300 (emendation).

Generic characters.—Facial disk incomplete; ear tufts long; tarsus completely feathered; toes without hairs or bristles; inner toe shorter than middle toe; inner side of middle claw with a

sharp edge, not pectinate;⁸ tail about half as long as wing; inner web emarginate on four outer primaries.

Only two species of this genus are known; namely, *P. badius* (Horsfield) and *P. assimilis* Hume. The first is found in the eastern Himalayas, Burma, the Malay Peninsula, Java, and Borneo. The second is confined to Ceylon. A specimen from Samar may belong to the type species, but probably it represents an undescribed race. I have no specimen of *P. badius*, so can make no comparisons.

PHODILUS RIVERÆ sp. nov.

Specific characters.—A medium-sized owl; general color of upper parts chestnut with irregular, bold black streaks; scapulars warm buff on outer webs, the tips black; lighter below, cinnamon rufous anteriorly, pinkish cinnamon posteriorly, with a few bold blackish brown shaft stripes; middle of abdomen white.

Type.—No. 13346, male, Bureau of Science. Collected at Loquilocon, Wright (Paranas), Samar, June 9, 1924, by R. C. McGregor and party. Iris brown; bill dull greenish, the tip white; feet gray; nails gray, tips blackish. Length of skin, about 320 millimeters; wing, 220; tail, 115; culmen from base, 35; bill from nostril, 23; tarsus, 54. This species is named for my assistant Francisco Rivera, who flushed the bird from a wooded hillside. The stomach contained the remains of a small snake.

CAPRIMULGUS JOTAKA Temminck and Schlegel.

Among some specimens collected in Mindoro by B. Barboza, Mr. W. Parsons and I found a male of the Japanese nightjar, which was killed near Calapan on March 19 (1908?). This species has been recorded several times from Palawan and once from Calayan, one of the small islands north of Luzon, and will probably be found in Luzon and other large islands.

CHÆTURA DUBIA McGregor.

In April, 1925, large swifts were fairly abundant at Balete Pass (altitude about 1,000 meters), on the road between Nueva

⁸ The claw is certainly not pectinate in the only specimen at hand, but this may be an individual variation. Blanford, *Fauna Brit. India*, Bds. 3 (1895) 268, in a footnote, says that the serration or pectination in good specimens, of which there are between twenty and thirty in the British Museum, is precisely similar to that of *Strix*. Wait, *Birds of Ceylon* (1925) 245, under the subfamily Photodilinae, says: "As in the genus *Tyto*, the inner margin of the middle claw is furnished with a slightly serrated, file-like process, or comb."

Ecija and Nueva Vizcaya Provinces, Luzon. The birds were most in evidence in the early morning and early evening. They flew from one side of the mountain to the other, passing fairly low over the small cleared area near the rest house. On April 10, Dr. Otto Bartels, of Manila, shot a female (Bureau of Science No. 13344), which is similar to the female type of *Chætura dubia* from Mindoro, but has longer wings and tail.

XEOCEPHUS CYANESCENS Sharpe.

Andres Celestino collected a slightly immature male of the large blue flycatcher on Bantac, a small island about 16 kilometers northeast of Busuanga, Palawan Province, on October 12, 1922. This specimen closely resembles the young male described by me some time ago,⁹ except that in the former the head, the chin, and the throat are fully feathered and of almost the same blue as in the adult.

CHLOROPSIS FLAVIPENNIS (Tweeddale).

A female of the yellow-quilled leafbird was collected by Andres Celestino, near Davao, Mindanao, on September 26, 1922. I can find no difference between this specimen and two females that were collected in Cebu in October.

KITTACINCLA NIGRA Sharpe.

Andres Celestino collected a slightly immature male of the Palawan shama on Bantac Island,¹⁰ Palawan Province, on October 12, 1922. This specimen has most of the black and white plumage of the adult, but some of the wing quills and their coverts are edged with tawny to ochraceous tawny and the flanks are slightly tawny. The three outer, white rectrices are fully grown, but the inner, black ones are shorter than the outermost white pair. In a young female collected at Puerto Princesa, June 27, 1910, by Worcester and Celestino, the entire head, neck, back, chin, throat, and breast are spotted.

Genus PRIONOCHILUS Strickland

Prionochilus STRICKLAND, Proc. Zool. Soc. London (1841) 29.

Anaimos REICHENBACH, Handbuch der speciellen Ornithologie, Scansoriae (1853) 245.

In the original generic description Strickland assigns three of Temminck's species to *Prionochilus* and enumerates them as *P. percussus*, *P. thoracicus*, and *P. maculatus*. Sharpe¹¹ gives

⁹ Philip Journ. Sci. 18 (1921) 79.

¹⁰ See antea, under *Xeocephus cyanescens*.

¹¹ Cat. Bds. Brit. Mus. 10 (1885) 63.

the type as "*P. ignicapillus*," doubtless meaning *Dicæum ignicapillum* Eyton, a species not mentioned by Strickland. Oberholser¹² mentions the fixation of the type, by Gray, in 1842, as *Pardalotus percussus* Temminck. He rejects *Prionochilus* because of *Prionocheilus* Chevrolat, 1837, used for a genus of Coleoptera. Oberholser proposes to use *Anaimos* Reichenbach, 1853. This name is mentioned by Sharpe, but the date is misprinted 1883. (This error is repeated by both Oberholser and Hartert.) Stuart Baker¹³ and Hartert retain *Prionochilus*, and Hartert¹⁴ says—

Oberholser rejects the name *Prionochilus* because of the earlier name *Prionocheilus*, and adopted the name *Anaimos* Reichenbach, 1883. Though the two names are evidently only different Latin renderings of the same Greek name, I suppose they are easily distinguishable and should both be accepted. No nomenclatorial rule demands the contrary.

PRIONOCHILUS PARSONSI sp. nov. Fig. 1. b.

Specific characters.—Male similar to the male of *Prionochilus olivaceus* Tweeddale, but lores, cheeks, and sides of throat and of breast black, not mouse gray. No sign of white on lores. In the female the black is replaced by dark mouse gray.

Type.—No. 13345, male, Bureau of Science. Collected at Malinao, Tayabas Province, Luzon, January 9, 1926, by Francisco Rivera.

Description of type.—Upper parts greenish yellow (near Ridgway's pyrite yellow), extending to sides of neck, and a wide line under eye; lores and sides of chin, throat, and breast black; center of chin, throat, and breast, and abdomen and under tail coverts white; flanks black and white, lightly washed with olivaceous; thighs black and white; axillars, wing lining, and long pectoral tufts white. Bill, legs, and nails black. Wing, 55 millimeters; tail, 30; culmen from base, 11; tarsus, 14.5.

Female.—Malinao, Tayabas Province, Luzon; January 9, 1926; Francisco Rivera, collector. Collection of W. Parsons. Similar to the male, but the black replaced by dark mouse gray, much darker than the gray areas of *P. olivaceus*. Bill, legs, and nails black. Wing, 53 millimeters; tail, 24; culmen from base, 10; tarsus, 15.

¹² Smiths. Misc. Colls. article 7, 60 (1913) 22. Article 7 was published on October 26, 1912.

¹³ Hand-list Bds. Indian Empire (1923) 125.

¹⁴ Nov. Zool. 27 (1920) 430, footnote.

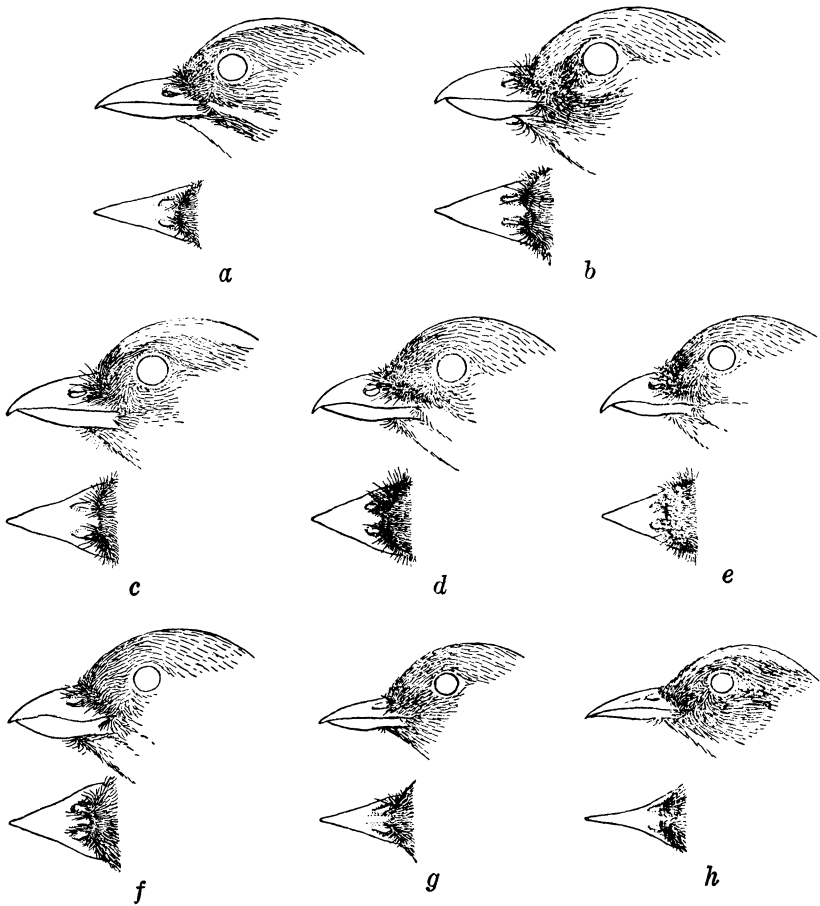


FIG. 1. Bills of various species of *Prionochilus* and of the genotype of *Dicæum*; a, *Prionochilus johannæ* Sharpe; b, *P. parsonsi* sp. nov.; c, *P. anthonyi* McGregor; d, *P. quadricolor* Tweeddale; e, *P. inexpectatus* Hartert; f, *P. æruginosus* Bourns and Worcester; g, *P. squalidus* (Burton); h, *Dicæum cruentatum* (Linnæus).

The type of *Prionochilus olivaceus* came from Dinagat Island, east of Leyte and north of Mindanao, and the species has been recorded from Basilan, Mindanao, Bohol, Samar, and Leyte. I have at hand three males and two females from Basilan, one female from Bohol, and one male from Samar. These specimens show neither sexual nor individual differences, except that the gray of the lower parts is slightly darker in the males. In all except the male from Samar the bases of the loreal feathers are white. In *P. parsonsi* there is no sign of white on the lores,

and the sexes are strikingly different in color. This species is named for Mr. William Parsons, of Manila, in recognition of his interest in Philippine ornithology.

In the Bureau of Science collection there is a male *Prionochilus olivaceus* of the year that was collected by Bourns and Worcester at Catbalogan, Samar, on August 15, 1892. This probably indicates that eggs were laid early in June.

Prionochilus samarensis Steere¹⁵ is described as differing from *P. olivaceus* "in having the breast and sides of the throat ash brown, nearly snuff brown, instead of ashy olive." Grant¹⁶ did not recognize this as a valid species, and until I see more material I shall follow Grant.

Subgenus POLISORNIS novum

Type, *Prionochilus anthonyi* McGregor.

Family Dicæidæ; differs from *Prionochilus* Strickland (type, *Pardalotus percussus* Temminck) in having the bill shorter and wider. Serrations of the bill obsolete and extending for a shorter distance from the tip; those of lower mandible scarcely distinguishable. Loral bristles numerous, extending forward and upward, partly protecting but not concealing the nostrils; no bristles on nasal operculum. Tenth primary lacking, the outermost about 3 millimeters short of tip of wing. Tail square, without white spots.

Seemingly, *Prionochilus quadricolor* and *P. bicolor* belong to this subgenus also; surely, Sharpe's¹⁷ assignment of them to different genera is incorrect.

Sharpe,¹⁸ in the monograph of the Dicæidæ, subordinates *Pachyglossa* Hodgson (1843) type *Micrura melanoxantha*, *Piprisoma* Blyth (1844) type *Pipra squalida*, and *Anaimos* Reichenbach (1853) type *Pardalotus thoracicus* as synonyms of *Prionochilus* Strickland (1841) type *Pardalotus percussus*. Oates¹⁹ recognizes *Prionochilus*, *Pachyglossa*, and *Piprisoma* as valid genera and adds *Acmonorhynchus*, type and only species *Prionochilus vincens*. Dubois²⁰ unites all under *Prionochilus*. Sharpe²¹ recognizes all of these genera except *Anaimos*. The species of

¹⁵ Birds and Mammals of the Steere Expedition (1890) 22.

¹⁶ Ibis (1897) 239.

¹⁷ Hand-list 5 (1909) 31.

¹⁸ Cat. Birds Brit. Mus. 10 (1885) 63.

¹⁹ Fauna Brit. India, Bds. 2 (1890) 381-386.

²⁰ Syn. Av. 1 (1902) 674.

²¹ Hand-list 5 (1909) 30-32.

these genera as arranged by Sharpe, with the addition of three Philippine species not known to him, are the following:

Prionochilus:

- percussus* (Temminck), genotype.
- ignecapillus* (Eyton).
- xanthopygius* Salvadori.
- johannæ* Sharpe, synonym, *plateni* Blasius. Palawan.
- thoracicus* (Temminck).
- maculatus* (Temminck).
- obsoletus* (Müller and Schlegel).
- olivaceus* Tweeddale. Philippines.
- parsonsi* sp. nov. Not known to Sharpe.
- everetti* Sharpe.
- anthonyi* McGregor. Not known to Sharpe.
- bicolor* Bourns and Worcester. Philippines.
- inexpectatus* Hartert. Philippines.

Acmonorhynchus:

- vincens* (Sclater), genotype.
- æruginosus* (Bourns and Worcester). Philippines.
- affinis* Zimmer. Not known to Sharpe.
- quadricolor* (Tweeddale). Philippines.
- aureolimbatus* (Wallace).
- sangirensis* (Salvadori).
- annæ* Büttikofer.

Piprisoma:

- squalidum* (Burton), genotype.
- modestum* (Hume).

Pachyglossa:

- melanoxantha* Hodgson, genotype.

I have one specimen of *Prionochilus ignecapillus*; this species resembles *P. johannæ* in the color pattern as well as in the rather slender bill and short distal primary. *Prionochilus maculatus*, of India, has a shorter distal primary and the bill is similar to that of *P. ignecapillus*; above there is a similar red crown patch, but the general color is green instead of blue; the colors of the underparts are white, yellow, and dark olive, arranged in a pattern similar to that of *P. olivaceus* of the Philippines. The last-named species has a wider bill. I have no specimen of *P. percussus*.

Prionochilus æruginosus Bourns and Worcester, transferred to *Piprisoma* by Grant,²² resembles *Piprisoma squalidum* (genotype)²³ in having no tenth primary and in the pattern of the

²² Ibis (1895) 454.

²³ I have examined but one specimen, loaned by the United States National Museum.

dull streaked plumage. Grant says, on the basis of a single specimen, that the Bourns and Worcester species has "the nostrils perfectly bare of hairs." This is not true of numerous specimens before me, for they have as many loreal hairs, overhanging and partly concealing the nostrils, as do the typical species of *Prionochilus*, and some have more. There are also short hairs on the upper border of the nasal operculum. The Bourns and Worcester species has a very stubby bill, actually equal in length to that of *Piprisoma squalidum*, but much wider and deeper; the length of gonys is equal to a ramus. This species does not seem to be a *Piprisoma*; Sharpe put it in *Acmonorhynchus*, a genus that was described for *Prionochilus vincens* with the following diagnosis: ²⁴

It differs from both these genera [*Prionochilus* and *Pachyglossa*] in possessing only nine primaries. From *Dicæum* it may be recognized by its very large, coarse bill, and from *Piprisoma* by its rounded tail and the numerous hairs which cover the nostrils.

In Oates's text figure showing the head of *Acmonorhynchus vincens* the nostril appears to be entirely covered by hairs, but the drawing is too small to show whether these hairs spring from the lore or partly from the upper border of the nostril.

Prionochilus æruginosus has a square tail and a white spot on the inner web of the outermost two rectrices. The color pattern is different from that of *Acmonorhynchus vincens*, judging from the descriptions; I have seen no specimen of the latter.

Hartert ²⁵ calls attention to the difficulty in using the key to the genera of Dicæidæ, ²⁶ because *Prionochilus* falls in the section "With a distinct bastard primary," whereas some of the species placed in that genus by Sharpe have no first primary.

Hartert says further—

If the absence or presence of a distinct bastard primary is a good generic character, the species without a distinct bastard primary must either be united with *Dicæum*, or be kept generically distinct under the name of *Pachyglossa* Blyth.

Unfortunately, I have never seen an example of *Pachyglossa*, but after reading Oates's diagnosis ²⁷ I assumed that *Pachyglossa* offers as much difficulty to the species in question as does *Prionochilus*.

²⁴ Oates, Fauna Brit. India, Bds. 2 (1890) 381, fig. 105.

²⁵ Novit. Zool. 2 (1895) 65.

²⁶ Cat. Bds. Brit. Mus. 10 (1885) 2.

²⁷ Fauna Brit. India, Bds. 2 (1890) 485.

Without any desire to increase the number of genera among the known species of this group, I propose two new subgeneric names as follows:

Polisornis subg. nov., type, *Prionochilus anthonyi* McGregor; other species of the subgenus, *Prionochilus quadricolor* Tweeddale, *P. bicolor* Bourns and Worcester, *P. inexpectatus* Hartert. From "Polis," type locality of the type species, and "ornis."

Bournsia subg. nov., type, *Prionochilus æruginosus* Bourns and Worcester; other species of the subgenus, *Acmonorhynchus affinis* Zimmer. Named for Frank S. Bourns, an American physician and naturalist, a member of the Steere Expedition and of the Manage Expedition.

Prionochilus johannæ, confined to Palawan, is the only Philippine species that is a strictly typical member of the genus; in other words, *Prionochilus* is not represented in the Philippines by a typical species, outside of Palawan.

If all of the Philippine species of the thick-billed Dicæidæ be kept in *Prionochilus* they should be arranged as follows:

Genus *Prionochilus*:

Subgenus *Prionochilus*—

johannæ Sharpe.

olivaceus Tweeddale.

parsonsi sp. nov.

Subgenus *Polisornis*—

anthonyi McGregor.

quadricolor Tweeddale.

bicolor Bourns and Worcester.

inexpectatus Hartert.

Subgenus *Bournsia*—

æruginosus Bourns and Worcester.

affinis (Zimmer).

STURNIA PHILIPPENSIS (Forster).

Three specimens of the violet-backed starling were collected by Andres Celestino on Linapacan Island, between Palawan and Culion, on October 10, 1922. This species has been recorded from Palawan and from a few other islands of the Philippines. It appears during migration and may be very abundant for a few days. A somewhat similar species, *Sturnia sinensis* (Gmelin), has been recorded from Calayan and Luzon, and should be watched for when the commoner species appears.

ILLUSTRATIONS

PLATE 1

Gallicolumba keayi (Clarke); $\times \frac{3}{8}$. (Water-color drawing from a specimen in the flesh, by Macario Ligaya.)

PLATE 2

Pithecophaga jefferyi Grant. (Photographs of a living bird from Pagbilao, Tayabas Province, Luzon, by Eustaquio Cortes.)

TEXT FIGURE

FIG. 1. Bills of various species of *Prionochilus* and of the genotype of *Dicaeum*; $\times 1\frac{1}{2}$. (Drawings by Macario Ligaya.)

- a, *Prionochilus* (*Prionochilus*) *johannæ* Sharpe; Palawan, male.
- b, *Prionochilus* (*Prionochilus*) *parsonsi* sp. nov.; Luzon, male; drawn from the type.
- c, *Prionochilus* (*Polisornis*) *anthonyi* McGregor; Luzon, male; drawn from the type.
- d, *Prionochilus* (*Polisornis*) *quadricolor* Tweeddale; Cebu, male.
- e, *Prionochilus* (*Polisornis*) *inexpectatus* Hartert; Luzon, male.
- f, *Prionochilus* (*Bournsia*) *æruginosus* Bourns and Worcester; Luzon, female.
- g, *Prionochilus* (*Piprisoma*) *squalidus* (Burton); Assam, India, female, A. M. Primrose, collector. United States National Museum No. 263739.
- h, *Dicaeum cruentatum* (Linnæus), genotype; Trong (or Trang), Siam, male, W. L. Abbott, collector. Bureau of Science No. 10072; ex United States National Museum No. 154193.

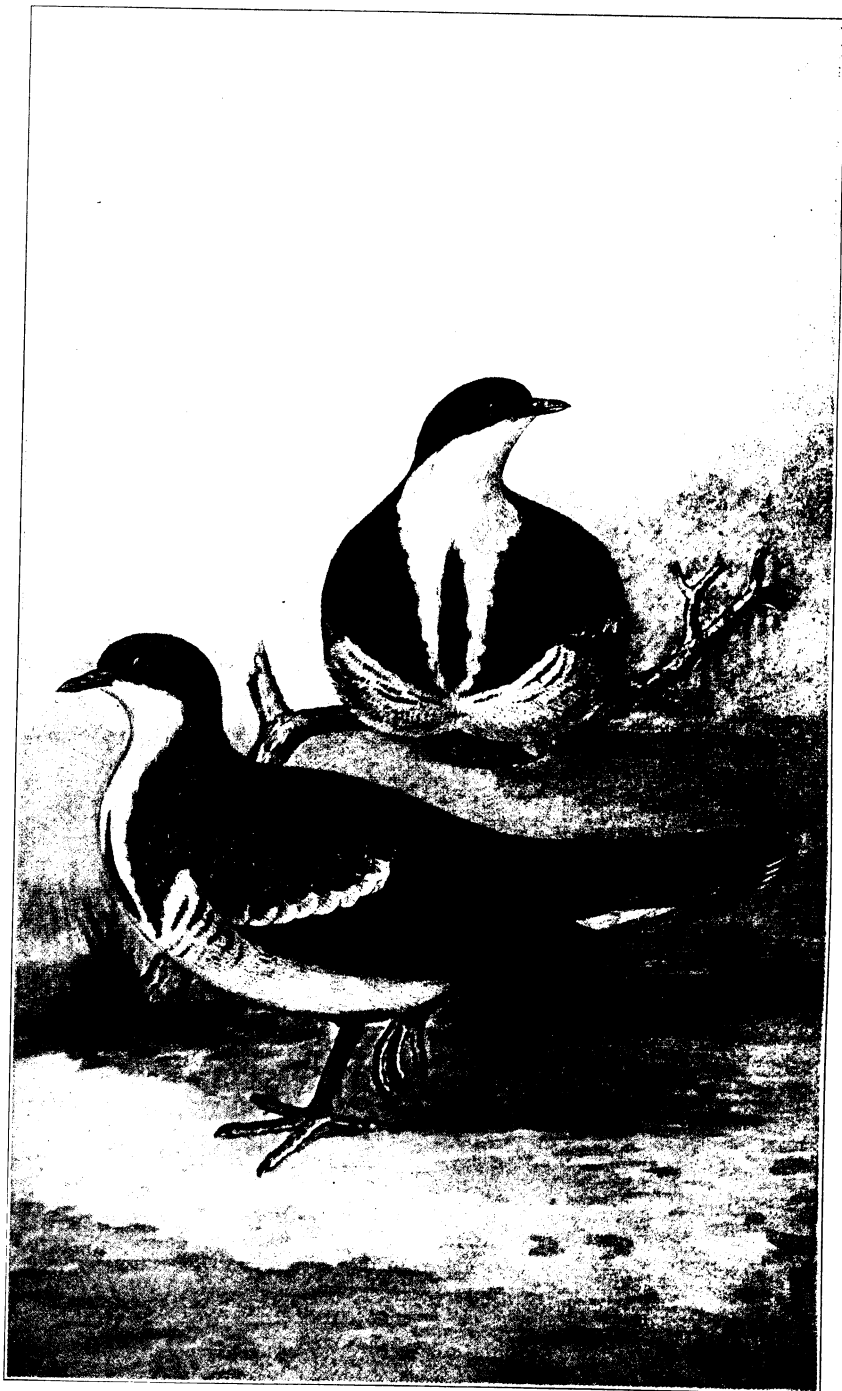


PLATE 1. GALLICOLUMBA KEAYI (CLARKE).





PLATE 2. PITHECOPHAGA JEFFERYI GRANT.



SOME PHILIPPINE AND MALAYSIAN MACHÆROTIDÆ (CERCOPIOIDEA)

By C. F. BAKER

Of Los Baños, Philippine Islands

FOUR PLATES

In a previous paper ¹ an attempt was made to review the true machærotids of Malaysia and the Philippines. Without sufficient material it was impossible to include in that paper the allies of *Enderleinia*. In the seven years intervening, some remarkable relatives of *Enderleinia* have been found in the Philippines and considerable Australian material of the same group has come to hand, some collected by Mr. H. Peterson, and some loaned by the Australian Museum at Sydney and by the South Australian Museum at Adelaide.² This has made possible a rearrangement of the whole group. Certain genera previously supposed to be Cercopidæ s. str. (=Aphrophorinæ auctt.) have been found to be true machærotids. While the Australian species are still in more or less confusion, the relationships of the genera are now clear, and it is possible to recognize *Hindola* as the typical genus of its subfamily with various other genera grouped closely about it.

Both *Clastoptera* (Neotropical) and *Iba* (Palæotropical) present some striking resemblances to certain machærotids in their elongate scutella and tegminal venation and appendices. These genera are, however, as far from Machærotidæ as from Cercopidæ s. str. and should constitute a separate family. Besides, they are not tube-dwellers. No representative of the Machærotidæ is known from the Americas.

In the Cercopioidea, just as in the Jassoidea, there is in general a remarkable uniformity, even through series of types quite diverse otherwise, in the venation of the hind wings, in strong contrast with the high degree of modification in the venation of the tegmina. Therefore, where distinct departures occur in the wing venation, these are of great importance in taxonomy,

¹ Philip. Journ. Sci. 15 (1919) 67-78, pls. 1-3.

² The Australian material will be fully treated in a forthcoming paper.

as in the eupterygids, balcluthids, and machærotids. In other characters the machærotids present the greatest range of body structure in the Cercopioidea, but certain venational characters are highly uniform and diagnostic.

Superfamily CERCOPIOIDEA

Key to families.

*a*¹. Outer fork of radius in hind wings always present (sometimes broken at apex), thus forming a supernumerary (first) apical cell, the cubitus apically forked or simple; claval veins (if present) usually distant and without connecting cross vein; scutellum comparatively small and short (except in Clastopteridæ).

*b*¹. Pronotal margin between eyes usually straight or slightly arcuate; front commonly more or less swollen apically; supraantennal ridges thickened and lobate; pronotum commonly strongly enlarged and much broader than head, and with anterolateral margins usually as long as or longer than posterolateral.

Tomaspididæ (=Cercopinæ auct., =Rhinaulacinæ auct.).

*b*². Pronotal margin between eyes usually strongly arcuate or subangulate; front usually swollen basally, if at all; supraantennal ridges not lobate, or greatly thickened; pronotum never greatly enlarged and rarely much wider than head, the anterolateral margins usually much shorter than the posterolateral.

*c*¹. Clavus narrowly acute or subacute apically; corial appendix either a narrow continuous membranous margin or wanting, never bent inward beyond clavus to overlap at end of body; corial venation various, but never as in Clastopteridæ; scutellum usually much shorter than pronotum.

Cercopidæ s. str. (=Aphrophorinæ auct., =Ptyelinæ auct.).

*c*². Clavus obliquely truncate at apex; corial appendix divided into two very broad subequal portions, these at rest infolded at end of the short and broad body to overlap; fork of radius in wing forming a very short first apical cell considerably before apex; cubitus in wings not forked apically; corium with three apical cells and two (or less) subapicals; scutellum longer than pronotum.

Clastopteridæ (including Ibaini).

*a*². Outer fork of radius in wing always absent, therefore no supernumerary (first) apical cell; claval veins (when two) adnate at middle or with a connecting cross vein; scutellum as long as or longer than pronotum, either simply long acuminate, or greatly elevated posteriorly and with a strongly curved free apical spine projecting caudad **Machærotidæ.**

MACHÆROTIDÆ

Key to subfamilies.

*a*¹. Scutellum not raised apically or with free apical spinous appendage; anterolateral margins of pronotum always very short, far shorter than posterolateral margins, the hind margin always more or less

deeply emarginate; anterior margin of pronotum strongly extended between eyes; head never broader than anterior width of pronotum and never strongly roundly swollen in front of eyes, usually obtuse-angulate; cubitus in hind wing apically forked; four apical corial cells arranged obliquely or even transversely to long axis of corium, the third from within never pedicellate or strongly projecting beyond and apically bounding fourth (outer).

Hindoliinæ (= Enderleiniinæ).

- a*³. Scutellum usually greatly raised apically, always with a free apical spinous appendage extended caudad; anterolateral margins of pronotum longer than posterolateral, the hind margin not or but very shallowly emarginate; anterior margin of pronotum but very slightly extended between eyes; head somewhat broader than anterior width of pronotum and strongly, usually roundly, swollen and extended in front of eyes; cubitus in hind wings not forked; four apical corial cells arranged nearly longitudinally (in line with long axis of tegmen), the third from within pedicellate and extending strongly beyond and apically bounding fourth (outer).
- b*¹. Form slender, body of scutellum high arched posteriorly with strong dorsal furrow; pronotum without laminately extended lateral angles; anterior margin of pronotum somewhat angulate between eyes **Machærotinæ.**
- c*¹. Frons not vertically produced; hind tibiæ without lateral spur. **Machærotini.**
- c*². Frons vertically angularly produced to high above head; hind tibiæ with one lateral spur..... **Sigmasomini.**
- b*². Form very thick and stout; body of scutellum nearly flat and with dorsal furrow subobsolete; pronotum with lateral angles produced into high, thin, spreading laminæ; anterior margin of pronotum broadly, gently arcuate between eyes..... **Maxudeinæ.**

HINDOLIINÆ

Key to genera.

- a*¹. Clavus narrowly acute apically, its terminal appendix very small and narrow; body more elongate, not clastopteroid, the tegmina never bent inward beyond clavus (*Hindolini*).
- b*¹. Scutellum basally strongly convexly raised above highest part of pronotum; pronotum smooth, finely punctured; crown of head nearly vertical, the head very short and broadly rounded (profile) from base to apex; tegmen with numerous irregular cells occupying apical half; two claval veins adnate at middle. **Apomachærota** Schmidt.
- b*². Scutellum basally never raised above highest part of pronotum; crown of head usually oblique; tegmen with three or four very regular apical cells and two or three anteapicals.
- c*¹. Claval veins separated and joined at middle only by a cross vein; scutellum with an elongate fossa.
- d*¹. Anteapical cells elongate and subequal in length; cubitus distant from claval suture throughout; both claval veins forked apically. (East Africa.)..... **Neuromachærota** Schmidt.

- d*². Anteapical cells broad, the second much shorter than the others; cubitus apically approximate to claval suture; claval veins simple; pronotum strongly transversely wrinkled; tegminal veins with scattered black granulations; head as wide as pronotum, the latter rather broadly arcuate-margined between eyes; scutellum shorter than pronotum. (Ceylon.)

Machæropsis Melichar.

- c*². Claval veins always adnate for some distance at middle.

- d*¹. Scutellum longer than pronotum and apically with two high, longitudinal, raised edges, forming a large, deep fossa; hind tibiæ with two strong subapical spurs. (Togo.)

Enderleinia Schmidt.

- d*². Scutellum simple or with but slight discal depression; hind tibiæ with but one subapical spur (though frequently also with a reduced subbasal spur.)

- e*¹. Cubitus lying for some distance at middle, on the claval suture, strongly curved, the base and apex distant from claval suture; corium with two subapical cells, second short; scutellum longer than pronotum; head a little more than half the width of pronotum.....*Serreia* g. nov.

- e*². Cubitus distant from claval suture and nearly straight; corium with three anteapical cells, the middle hardly half the length of the other two; scutellum shorter than pronotum; head but slightly narrower than pronotum.

- f*¹. Scutellum with a large, shallow, subcircular depression occupying a large part of disk; crown, pronotum, and scutellum with very large, deep, crowded punctures; claval and part of corial veins with scattered dark granules, some of which near apex are bullate; all the veins strong and dark; crown (profile) lying in plane of anterior slope of pronotum and not at all depressed; hind tibia with a very large spur at middle.....*Parahindola* g. nov.

- f*². Scutellum plane or slightly convex, smooth; hind tibial spur always nearer to apex than to base.

- g*¹. Body slenderer, not thickened and robust; head very little, if any, narrower than pronotum; surface of the largely subhyaline tegmina nearly plane, veins usually weak and indistinct, pronotum coarsely or finely punctured, and often with indications of transverse rugæ or wrinkles, but the puncturing usually predominant; sexes very similar.

Hindola Stål (= *Pectinariophyes* Kirkaldy = *Polytrichophyes* Schmidt = *Modiglianella* Schmidt = *Taihorina* Schumacher, = *Quinquatrus* Distant, = *Xenaias* Distant).

- g*². Body thick and robust; head appreciably narrower than pronotum, the latter strongly transversely wrinkled with more or less of intermingled punctures; surface of tegmina strongly irregular with deep depressions be-

tween the strong veins, the tegmina as a whole rather strongly convex; sexes strongly dimorphic.

Chaetophyes Schmidt.

*a*². Clavus broad apically, obliquely subtruncate, its terminal appendix short but broad; form of body rather strikingly clastopteroid, short and compact, the tegmina apically bent across apex of body behind clavus, and there overlapping; crown broadly rounded on to the strongly convex face (*Hindoloidesini*).

*b*¹. Veins scattered granulate on the subhyaline corium; crown almost vertical, very short, transverse; corium with three small apical cells; corial appendix not yet described or figured.

Polychætophyes Kirkaldy.³

*b*². Veins not granulate, the discal veins very obscure except by transmitted light; crown oblique, more elongate; terminal corial appendix of great width with subparallel inner and outer margins, and reaching entirely across apex of tegmina; corium with apical cells entirely absent..... **Hindoloides** Distant.

Genus CONMACHÆROTA Schmidt

In a synopsis of the Malaysian species of the genus *Machærota* Burmeister⁴ the species were divided into two groups, the first comprising those with the claval vein apically forked (possibly two partly adnate claval veins) and the second those with the claval vein (single) simple. Between the writing of this paper and its publication, Schmidt⁵ separated the first group as a distinct genus under the name *Conmachærota*, with *notoceras* Schmidt as the type. Two new species of this group have recently been encountered in the Philippines, and their relation to the species previously discussed is given in the following key.

Key to species of the genus Conmachærota Schmidt.

*a*¹. Pronotum and scutellum in profile very broad, the narrow, basal portion of scutellum very short, basal portion of scutellum with a prominent yellow stripe on either side; length of crown much more than half the width between eyes; greatest profile width of scutellum into length of spine twice or a little more.

*b*¹. Scutellum in profile with greatest width much less than length; basal portion forming a distinct "neck;" its dorsal sulcus reaching about half the length of body of scutellum.

*c*¹. Females pale in color, males much darker; body densely fine pubescent; entire scutellum about twice as long as head and thorax together; crown anteriorly rather broadly rounded.

C. notoceras Schmidt.

³ Possibly founded on males of *Hindola* or *Chaetophyes*, and may not belong to this tribe.

⁴ Philip. Journ. Sci. 15 (1919) 69.

⁵ Stett. Ent. Zeit. 79 (1918) 371.

- c². Female dark chocolate brown, same as males; body less densely pubescent; entire scutellum distinctly more than twice longer than head and thorax together; crown anteriorly subangulate at apex..... C. *mindanaensis* sp. nov.
- b². Scutellum in profile with greatest width about equal to length, basal portion not forming a distinct "neck;" its dorsal sulcus reaching about three-fourths of body of scutellum; crown anteriorly subangulate at apex..... C. *philippinensis* Baker.
- a². Pronotum and scutellum in profile very narrow, basal narrow portion of scutellum very long, this due to the strong flattening of both pronotum and scutellum; basal portion of scutellum without lateral yellow stripes; length of crown about half the width between eyes, anterior margin strongly subangulate; greatest profile width of scutellum into length of spine four times..... C. *attenuata* sp. nov.

CONMACHÆROTA MINDANAENSIS sp. nov.

Female.—Length to end of abdomen, 4.75 millimeters; to end of spine, 7.5; length of spine alone, 3.5.

Color of body very deep chocolate brown, the body of scutellum much paler, the spine golden brown. Broad central band of front shining black. Pale yellow are five oblique lines on sides of front, curved lateral stripes on body of scutellum, its apical margin below spine, the usual dorsal spot at base of spine, entire basal segment of abdomen and remaining tergites at middle, and basal article of hind tarsus except extreme base and apex.

Sculpturation very similar to that of *philippinensis*, but the median carina of pronotum is strong throughout, strongest on middle third. Scutellar sulcus (fig. 6) broader and shallower than in *philippinensis*. Crown subangulate anteriorly (fig. 5). Diagnostic characters otherwise as stated in the key. Proportions in profile as in fig. 4.

Male.—Length to end of abdomen, 4 millimeters; to end of tegmina, 5; to end of spine, 6.5.

Colors same as in the female, differing in this respect from both *notoceras* and *philippinensis*.

Appears to be common in northern Mindanao, specimens coming from Surigao, Surigao Province, and from Iligan, Lanao Province (*Baker*).

CONMACHÆROTA ATTENUATA sp. nov.

Male.—Length to end of abdomen, 3.5 millimeters; to end of tegmina, 5; to end of spine, 6.5.

Color very deep chocolate brown, body of scutellum not paler, the spine golden brown. Frons yellow with dark oblique stripes on sides; only the apex of crown (extreme base of frons) shining

black. Sides of body of scutellum entirely without yellow stripes, but area of sulcus paler, and hind margin narrowly yellowish. Lateral margins of pronotum very narrowly yellowish. Fore and middle legs pale fulvous. Hind basitarsus, except extreme base and apex, yellow. Abdomen without yellow markings except on basal tergite. Venation on apical half of tegmina darker than in either *notoceras*, *philippinensis*, or *mindanaensis*.

Sculpturation very similar to that of *mindanaensis*. Scutellar sulcus (fig. 3) short and small, less than one-half length of body of scutellum. Crown (fig. 2) more strongly angulate anteriorly. Diagnostic characters otherwise as in synopsis above. The profile proportions (fig. 1) are unique in this group.

A single specimen from Zamboanga, Mindanao (Baker).

Genus SERREIA novum

Diagnostic characters as given in the synopsis above. In general form this genus resembles the robust and strongly humpbacked *Apomachærota* and its allies rather than the slenderer, cercopoid *Hindola* and allies. Of the latter it resembles *Chaetophyes* in having the surface of the tegmina very uneven, with a deep, sharply curved, longitudinal depression on base of corium, and the apical and subapical cells concave. The corial appendix is much larger and reaches nearer to apex of corium (fig. 11) than in *Hindola* or any of its near relatives. The hind femora are shallowly concave on lower surface, subequal in length to hind tarsi, and much shorter than their tibiæ; hind tarsi with first article (seen from above) subequal to remaining two together; hind tibiæ with subapical spur very stout, the basal minute. The rostrum slightly surpasses the middle coxæ.

This notable genus is dedicated to a notable man, Mons. Paul Serre, Consul of France, "citizen of the world," formerly resident of many tropical countries, now in Auckland, New Zealand. He is accomplished in agricultural science and takes an enthusiastic interest in all scientific endeavor. He is widely known for his thoroughgoing monographs on Havana tobacco and New Zealand hemp.

SERREIA NOTABILIS sp. nov.

Female.—Length to end of closed tegmina, 7 millimeters; width of head, 2; of pronotum, 3; length of tegmen, 5.75; width at end of clavus, 3.5.

Color deep chocolate brown, head, pronotum, and tegmina smooth and shining. Face and all below somewhat paler and with a yellowish cast; the slight convexity before apex of scutellum with a sordid yellowish transverse mark. Frons without oblique dark lateral arcs. Tegmen hyaline, the yellowish veins margined throughout middle of corium with minute brown dots, with two discal groups of such dots, the larger proximal one extending to costal margin, the distal smaller one at base of the anteapical cell; the veins bordering apical cells broadly margined with very deep chocolate brown, cubital veins with several larger superposed brown dots. Corial appendix smoky at base and at apex. Clavus suffused with pale yellowish which narrowly invades corium, the inner apical fork of claval vein margined with minute brown dots.

Frons shining, minutely obscurely wrinkled with shallow, oblique lateral folds near base; loræ with scattered large punctures. Clypeus (fig. 10) strongly compressed apically, forming a high median ridge, the lateral surfaces of this portion concave and coarsely transversely wrinkled. Crown shining, but the surface very uneven due to low, coarse, indistinct wrinkles of no regular arrangement. In direct view vertical to crown (fig. 7), the length of crown is more than three-fourths width between eyes, the distance between ocelli is less than length of true vertex; exposed superior surface of front as long as greatest width. Pronotum (fig. 8) smooth and shining with obsolescent coarse transversal wrinkles and large scattered punctures; no median carina. Length of pronotum two-thirds of its width, the anterior margin evenly arcuate, the posterior shallowly emarginate. Scutellum (fig. 9) evenly convex, smooth and shining with scattered obsolescent punctures, lying in the general curve of pronotum, and with the apical profile margin bisinuate. Venation of tegmen and wing as shown in figs. 11 and 12. Clavus near apex with a large, round, strongly convex, concolorous bulla.

Male.—Length to end of closed tegmina, 5.5 millimeters; width of head, 1.5; of pronotum, 2.5; length of tegmen, 4.5; width at end of clavus, 2.5.

Color darker than in female, the scutellum piceous. Veins of tegmina darker, the brown margins of apical veins narrower, the claval bulla shining black. Face and all below black or

piceous, legs a little paler. Puncturation of pronotum and scutellum deeper and the latter with quite obvious coarse transverse wrinkles.

Two specimens of this remarkable insect were taken near Zamboanga, Mindanao, and fortunately represent the two sexes.

A single male specimen which must be referred here, at least until the corresponding female is known, was taken on Mount Maquilung in central Luzon. It differs in having the hind legs pale yellowish, and the claval bulla not conspicuously shining black. It may bear the varietal name *luzonensis*.

Genus PARAHINDOLA novum

Diagnostic characters as in above generic synopsis. No member of the *Hindola* group of species possesses the unique scutellar structure of *P. borneensis*, and none possesses the extremely coarse sculpturation uniformly covering crown, pronotum, and scutellum. The shallow scutellar depression is roundish and saucer-shaped, but has a thickly obtuse and little raised rim. The subobsolete median pronotal carina is more distinct near the anterior margin. There is a greater number of cross veins in the outer (radial) cell, the cubital vein is more strongly curved, and the corial appendix is much longer than in *Hindola*. Hind tibiæ with a very large and long spur inserted at middle, only a minute rudiment of the subbasal spur remaining. Basal article of hind tarsi as long as the two distal together.

While in all species of *Hindola* known to me the general plane of face is nearly horizontal and lies nearly in line with the long axis of the body, in *Parahindola* it is distinctly oblique to the axial line.

PARAHINDOLA BORNEENSIS sp. nov.

Female.—Length to end of closed tegmina, 6.5 millimeters; width of head, 2.5; of pronotum, 2.75; length of tegmen, 5; width at end of clavus, 2.

Color stramineous; front chocolate brown; femora except apex piceous, remainder of legs pale brownish, hind tibiæ yellowish. Abdomen pale yellowish basally. Tegmina with basal fourth pale bronzy brownish, remainder hyaline; claval and basal corial veins indistinct, remainder dark and distinct; claval and basal corial veins with scattering superposed dark brown

dots and a sparse row of such dots about the entire outer corial periphery; veins on apical half of corium more or less broadly margined with deep brown.

Front a little shining above, subopaque below, very gently convex, the surface microscopically crowded lacunose with some scattered indistinct punctures on median area. Subantennal portion of cheek thickly rugose, subocellar area transversely wrinkled, loræ coarsely punctured. Crown (fig. 13) like pronotum and scutellum, with very coarse deep and crowded irregular punctures. Interocellar distance nearly equal to twice length of true vertex, superior face of front (vertical view) much wider than long, and at a little less than half its length from base with a strongly raised, arcuate transverse ridge, the surface posterior to this having the large punctures grouped in deeper cavities. Pronotum with median carina distinct only on anterior fourth; length somewhat less than two-thirds width, anterior margin medially subangulate, posteriorly very obtuse angulately emarginate. Surface of scutellum in profile view (fig. 14) nearly plane and lying considerably below the posterior convexity of pronotum, the apex depressed before the acuminate tip. Length of scutellum little greater than that of pronotum. Venation of tegmen as shown in fig. 15, the wing venation normal for this group. Tegmen shining, the clavus and basal half of corium with large, scattering shallow punctures. The two large brown spots on the two middle apical veins are somewhat bullate and the veins appear to be somewhat bent within them (not shown in the figure).

A single specimen taken at Sandakan, British North Borneo (Baker).

Genus *HINDOLA* Kirkaldy

Hindola was described by Stål⁶ as *Carystus* (praeocc.) and based upon *Ptyelus viridicans* Stål,⁷ a common species of Singapore. Later Spangberg⁸ described four species from Australia, none of which appears to be true *Hindola*. Never having seen true *Hindola*, Kirkaldy⁹ described *Pectinariophyes*, which is *Hindola*. *Polychætophyes* Kirkaldy is questionably a clastopteroid genus; but Kirkaldy referred to it a second species (*aequalior*) which evidently does not belong in it and

⁶ Berl. Ent. Zeit. 6 (1862) 303.

⁷ Ofv. Vet. Ak. Forh. 11 (1854) 251.

⁸ Ofv. Vet. Ak. Forh. 34 (1887).

⁹ Haw. Sugar Planters' Exp. Sta. Bull. 12 (1913) 10.

Schmidt, without having seen this very insufficiently described species, bases on it his genus *Polytrichophyes*.¹⁰ This also may be *Hindola*. Later Schmidt,¹¹ who had not seen *Hindola*, described *Modiglianella* from Sumatra and not one of the supposedly diagnostic characters given but falls within the limits of specific characters in *Hindola*.

Schumacher¹² describes a genus *Taihorina*, based upon *T. geisha* from Formosa. The numerous characters mentioned in the generic descriptions all fall within the range of specific characters in *Hindola*, which was evidently unknown to this author. The species, however, appears to be a distinct one. Finally, Distant, who knew *Hindola viridicans* and had described several other species of the genus, described a new genus, *Quinquatrus*,¹³ based upon *Q. dohertyi* from Tenasserim and another, called *Xenaias*, based upon *X. notandus* from the Nilgiris. His figures present nothing distinctive, and it is certain that no diagnostic characters are given. These, therefore, must also be referred questionably to synonymy until the details of structure, especially venation, are made known.

We were fortunately able to collect in Singapore a series of the type species of *Hindola* and with this as a starting point have been able to make illuminating comparisons with Australian, Bornean, and Philippine species. In this study it was found that some of the characters previously used as of generic significance were not even of specific value, the degree of obliquity of the head sometimes differing considerably in the two sexes. Also there are sometimes considerable sexual differences in sculpture, as has been indicated in the description of the scutellum of *Serreia*, as well as in color. The basal spur of the hind tarsi varies greatly in size and is often nearly or quite obsolete, and may be present on one side and absent on the other in a single specimen. In describing the genus, Stål refers to the transversely depressed crown with fore and hind borders raised. Some of the Australian species show this equally well, but this has all gradations to a crown that is obliquely plane and with only the hind margin raised or with neither margin elevated. In all we find the same general pattern of venation in the perfectly plane, subhyaline, rarely colored tegmina, the

¹⁰ Stett. Ent. Zeit. 73 (1912) 173.

¹¹ Stett. Ent. Zeit. 79 (1918) 366.

¹² Mitt. Zool. Mus. Berlin 8 (1915) 84.

¹³ Fauna Brit. Ind. Rhynch 6 (1916) 197.

veins usually decolored and inconspicuous except by transmitted light. The scutellum is evenly convex and usually very lightly punctuate or wrinkled. In the type species the pronotum is thickly, obliquely punctate-rugose and in other species there are variable admixtures of punctures and rugæ. Even those that have a preponderance of punctures will be found usually to have well-defined wrinkles laterally. Genera cannot be based on these differences. There is the greatest need, for a proper understanding of this group and its various species, to have rearings made of good series of both males and females from the curious calcareous tubes which the nymphs inhabit, and it is hoped that these remarkable insects will receive the active attention of all Indo-Malayan and Australian entomologists. The tubes in this group are much smaller than are those of *Machærota* and are more easily overlooked, but they are abundant in many districts, as the collection of mature forms shows. The correct association of the sexes in each case will help a great deal toward the proper elucidation of the species and also of the genera.

HINDOLA VIRIDICANS Stål.

Anatomical details of this common Singapore species, the type of the genus, are given in figs. 16 to 21. There is an appreciable difference in the length of the crown and in its obliquity in the two sexes. While the head (fig. 16) is in this species distinctly narrower than the pronotum, it varies to nearly as wide in some other species. The description of Stål gives clearly the general characters of the species. The extent of reddish suffusion on crown, pronotum, and scutellum is very variable.

HINDOLA LUZONENSIS sp. nov.

Male.—Length to end of closed tegmina, 6.25 millimeters; width of head, 2; of pronotum, 2.25; length of tegmen, 5.25; width at end of clavus, 2.

Color olive green, crown reddish stramineous; face piceous, a median oval frontal dot on line of antennal insertions; clypeus sordid yellowish. Mid and fore legs pale brownish, hind legs sordid yellowish. Inner half of clavus olive green, outer half and entire corium evenly pale chocolate brown.

Frons gently convex, slightly swollen basally, microscopically transversely lacunose, lateral raised arcs obsolete, entire genæ and loræ thickly finely rugose. Crown (fig. 22) with very

uneven surface, rather strongly depressed along frontal suture, on lateral area, and on disk of superior portion of front; hind margin sharply raised but anterior margin not raised; all parts of surface of crown with very coarse, obtuse, irregular wrinkles; in vertical view (fig. 23) the crown is rather strongly angulate anteriorly, the interocellar distance is actually subequal to the length of the true vertex (not apparent on the curved surface as seen from above). Length of pronotum two-thirds of its width, anteriorly obtusely subangulate, posteriorly very obtuse angulately emarginate, its surface rather strongly transversely punctate wrinkled. Scutellum not quite as long as pronotum on median line, its surface very slightly convex and finely transversely wrinkled. Tegmina densely, coarsely, very uniformly punctate throughout, resembling in this character some of the Australian species.

A single fully mature male taken at Baguio, Benguet Subprovince, northern Luzon (*Baker*). Another male specimen, juvenile and pale in color throughout, but with the same structural characters, and evidently of this species, was taken at Imugan, Nueva Vizcaya Province, not a great distance from Baguio.

One of the most deeply colored of this group, and in this resembling certain *Chaetophyes*, but in form and structure a typical *Hindola*.

HINDOLA FULVA sp. nov.

Female.—Length to end of tegmina, 4.75 millimeters; width of head, 2; length of tegmen, 3.75; width at end of clavus, 1.75.

Color of crown, pronotum, and scutellum deep uniform fulvous; a narrow transverse arcuate stripe before apical margin of pronotum pale yellowish; all below with pleuræ, abdomen, and legs pale yellowish. Tegmina hyaline; basal half of clavus somewhat thickened callose and lemon yellow; clavus apically with a pale brownish commissural spot; numerous very scattered brownish dots occur on the veins, most numerous near and along costal margin, the two middle apical veins with larger brownish spots.

Frons medially somewhat flattened, remainder gently convex; surface of front, genæ and loræ minutely, thickly, obscurely rugose. Entire surface of crown, pronotum, and scutellum thickly, deeply, but very minutely punctate-rugose, giving these surfaces a velvety appearance. Crown (fig. 26) somewhat depressed, most strongly in ocellular area, somewhat concave in

profile, though the general plane is oblique in general line of slope of anterior part of pronotum; interocellar distance slightly greater than length of true vertex; superior face of front sharp margined around its strong obtuse angulate apex, its surface with a blunt thick median wrinkle and its middle crossed transversely by a similar but arcuate wrinkle. Head and pronotum proportionally very broad, the former slightly the narrower. Pronotum with a strong median carina on anterior half, its length but little more than half the width. The posterolateral margins rather strongly sinuate. Scutellum considerably longer than pronotum, its surface gently evenly convex, slightly depressed before apex. Subbasal hind tibial spur stronger than usual but not half the size of subapical. Venation of tegmen and wing (figs. 27 and 28) typically that of *Hindola*, but corial appendix somewhat longer.

Male.—Length to end of tegmen, 4.5 millimeters; width of head, 1.75; length of tegmen, 3.5; width at end of clavus, 1.5. Closely similar in all respects to the female.

This species is not uncommon in Singapore and it will be of the highest interest and importance to discover its tubes and to compare them with those of *Hindola viridicans*.

It was this and the following species that led me to doubt the feasibility or wisdom of attempting to divide the *Hindola* group into several genera on our present knowledge. These two species have longer crown, broader head and pronotum, and a more compact squat appearance than has the type of *Hindola*. They also possess brown-dotted tegmina. The sculpture is as distinctive in its way as is that of *Parahindola*, but in another direction.

The next species, *nitida*, very close to *fulva* in form and structure, has sculpturation of an entirely different type. On close comparison of all of the above characters that might be used for generic distinction they were found to exist in all degrees in the various species, and in all combinations. The description of the following species will illustrate this point.

HINDOLA NITIDA sp. nov.

Female.—Length to end of tegmina, 4.75 millimeters; width of head, 2; length of tegmen, 3.75; width at end of clavus, 2.

Color olive green, usually with an evanescent reddish suffusion invading more or less of crown, pronotum, and scutellum. Sternum and lower half of face piceous, shading on face into sordid yellowish on upper half. All femora, except extreme bases and

apices, piceous, remainder of legs sordid yellowish. Tibial spurs as in *H. fulva*. Tegmina hyaline, extreme base and a narrow stripe extending from claval commissure before its apex to center of corium, pale brown; darker brownish dots occur on the veins as shown in fig. 31. Abdomen dark colored with the first tergite laterally conspicuously paler.

Frons very gently convex, smooth and shining, with slight, very indistinct, microscopical remnants of sculpturing; surface of clypeus, loræ and genæ thickly coarsely rugose. Crown (fig. 30) very similar to that of *H. fulva* but hind margin strongly raised, the superior frontal surface shorter for its breadth, with no transverse wrinkle, the median fold broader and more obscure. The pronotum (fig. 29) like that of *H. fulva* but median carina reduced to a remnant near anterior border, the surface shining, the sculpturing a delicate shallow transverse wrinkling with scattering punctures; this type of sculpturation is still more indistinct on the scutellum. Venation (fig. 31) closely similar to that of *H. fulva*.

Male.—Length to end of tegmina, 4 millimeters; width of head, 1.75; length of tegmen, 3.25; width at end of clavus, 1.5.

Very similar in all respects to the female, but in these specimens with the scutellum very strongly reddened.

This species was found to be not uncommon at Sandakan, British North Borneo (*Baker*). Differs from all other species in the short transverse brown stripe on clavus and inner half of corium.

Genus CHAETOPHYES Schmidt

This seems to represent a well-distinguished generic group. The body is very thick and stout and more "humpbacked" than in *Hindola*. The surface of tegmina is farther from uneven than in any *Hindola* and the width is greater in proportion to the length. The basal frontal suture is nearer to the ocelli (these being nearer to it than to base of head) a condition not noted in any *Hindola*. The interocellar distance is also proportionally less than the ocellocular. Form of crown, pronotum, and scutellum are indicated in figs. 32 and 33. The venation (figs. 34 and 35) is essentially that of *Hindola*. The cross vein in middle anteapical cell in fig. 34 is abnormal.

Several Walkerian species are to be referred here, and doubtless some of Spangberg's "*Hindolas*" belong here. One of the most marked characters of the genus lies in the strong dimor-

phism of the sexes. Schmidt described *Chaetophyes bicolor*¹⁴ from female specimens, while the smaller black males of the same species he described as *C. unicolor*. I have large series of these taken standing together on the same plant, the *bicolor* form all females, and the *unicolor* form all males. This species has apparently been redescribed by Hacker as *Polychætophyes perkinsi*.¹⁵ The acute clavus of the latter apparently excludes it from *Polychætophyes*. Walker seems, likewise, to have separated sexes of this group as distinct species.

Genus HINDOLOIDES Distant

Distant describes this genus¹⁶ with the species *H. indicans* from Calcutta, as a relative of *Hindola*, both of which he places among ptyeline cercopids. He does not remark its strong resemblance to *Clastoptera* nor the remarkable fact that the clavus is broadly truncate apically as in that genus. He speaks of three "apical cells" in corium, but apical cells are entirely absent (fig. 38), the cells present being the anteapicals of *Hindola*, the space of the apicals being occupied by the enormously developed corial appendix. The wing venation (fig. 39) is typically machærotid. Outlines of crown, pronotum, and scutellum are given in figs. 36 and 37. The figures are prepared from Calcutta specimens.

Kirkaldy gave a very imperfect description of *Polychætophyes* and did not figure the venation, but he apparently noted and appreciated the importance of the extraordinary structure of the clavus. Recently Hacker¹⁷ described a species, *appendiculata*, his figure showing the same remarkable corial appendix that occurs in *Hindoloides*, but which Kirkaldy does not mention for *Polychætophyes*. In Hacker's figure it appears that true apical cells are present in the corium, and this may distinguish it from *Hindoloides*. Kirkaldy may have overlooked the broad appendix which at rest is folded closely under the apex of abdomen. This emphasizes the great need of clear figures illustrating *Polychætophyes serpulida* Kirkaldy, the type of the genus.

¹⁴ Stett. Ent. Zeit. 79 (1918) 367.

¹⁵ Mem. Queensl. Mus. 8 (1926) 246, fig. 6.

¹⁶ Ann. & Mag. Nat. Hist. 16 (1915) 506.

¹⁷ Mem. Queensl. Mus. 8³ (1926) 247, fig. 1.

It is hoped that Indian entomologists will soon locate the calcareous tubes of *Hindoloides* and compare them with those of *Polychætophyes serpulida*, figured by both Hacker and Kirkaldy.

Hacker¹⁸ gives a very interesting account of the emergence of two of these remarkable tube-dwelling machærotids. His determination of the species, however, seems questionable as to *Polychætophyes*, the lower insect in his fig. 4 apparently being not of that genus at all, since it has an acute clavus. At any rate, *P. serpulida* of Hacker's figure and his later *P. appendiculata* have no near generic relationship. If Hacker's 1922 figure really represents *Polychætophyes*, then it seems possible that we are wrongly interpreting Kirkaldy's description of the clavus, in which case *Chætophyes* will be synonymous, and *Hindoloides* will stand quite by itself.

Some time after this paper was submitted for publication, Mr. W. E. China very kindly sent to me the accompanying illuminating figures (Plate 4) made directly from the types of *Quinquatrus* and *Xenaias*. These figures fully confirm my assignment of these two genera to *Hindola*. Distant's description of *Xenaias*¹⁹ is entirely made up of generalities applying to any member of this group. It is evident from Mr. China's figure that the minute basal spine was overlooked by Distant, since he described the posterior tibiæ as having only one spine; and this is a matter of no importance in this group, since the very weak basal spine may be present or absent in the same species. Mr. China remarks (in litt.) of *Xenaias notandus* Distant:

Pronotum strongly reticulately rugose, the reticulations fine and almost obsolete along the anterior margin and on vertex. Basal half of scutellum slightly concave, and rugose. Tegmina somewhat rugosely reticulate, extending about one-third their length beyond tip of abdomen; venation obscure, and variable in details.

To these points may be added the elongate form of tegmina with the very long anteapical cells, elongate third apical cell of wing, and wider vertex with slightly more angulate apex. All of these characters well mark the species *notandus*, but none of them can serve as generic distinctions since they all

¹⁸ Mem. Queensl. Mus. 7⁴ (1922) 282, 480, 2 pls.

¹⁹ Fauna Brit. Ind. Rhynch. 6 (1916) 198.

fall within the limits of *Hindola* species. I have already shown the occurrence of great variety in sculpture and form in various combinations in *Hindola*.

Quinquatrus (Plate 4, fig. 1) is just as clearly *Hindola*, the general lineaments, like those of *Xenaias*, being unmistakably those of *Hindola*. Of *Q. dohertyi* Mr. China (in litt.) says:

Anterior two-thirds of pronotum obliquely rugosely wrinkled on each side of middle line; the posterior third almost smooth. Anterior margin and vertex much more strongly and irregularly rugose. Tegmen obscurely, coarsely punctate: veins of tegmen obscure, somewhat variable in detail.

Distant described the same pronotal sculpture as "thickly finely punctate," and punctures will doubtless be evident among the rugose wrinkles in certain lights, a character of great variety in *Hindola*. Distant's statement "pronotum about twice as broad as centrally long," is entirely incorrect, even according to his own figure. His statement "tegmina with three apical cells" is also incorrect; but the outer apical cell in this group is often indistinct. There is no character mentioned in connection with this species that can possibly be used for generic distinction and it must therefore be left in *Hindola*, in the neighborhood of *H. fulva* and *H. nitida*, described above, which it resembles.

The cases of *Xenaias* and *Quinquatrus* clearly illustrate the utter insufficiency which characterizes the descriptions of Distant's genera of Cercopioidea, as well as of Jassoidea. Such anatomical figures as those presented by Mr. China would make it readily possible to understand all of them and to place them properly among other described genera. As it is, they are an almost insuperable obstacle to the formation of any usable classification of Indian and Malayan forms. Mr. China's magnanimous willingness to supply figures, in this as well as other cases of the sort, is very highly appreciated and is of the greatest constructive utility.

Since I wrote the above, my attention has been called to the fact that the genus *Hindoloides* has been redescribed by Haupt²⁰ under the name "*Weigoldella*."

²⁰ Deutsch. Ent. Zeitsch. (1923) 299.

ILLUSTRATIONS

PLATE 1

- FIGS. 1 to 3. *Conmachærota attenuata* sp. nov.; 1, profile of head, pronotum, and scutellum; 2, crown, vertical to its plane; 3, dorsum of body of scutellum.
- 4 to 6. *Conmachærota mindanaensis* sp. nov.; 4, profile of head, pronotum, and scutellum; 5, crown, vertical to its plane; 6, dorsum of body of scutellum.
- 7 to 12. *Serreia notabilis* sp. nov.; 7, crown, vertical to its plane; 8, pronotum; 9, profile of head, pronotum, and scutellum; 10, sublateral view of head; 11, tegmen; 12, wing.

PLATE 2

- FIGS. 13 to 15. *Parahindola borneensis* sp. nov.; 13, dorsum of head, pronotum, and scutellum; 14, profile view of head, pronotum, and scutellum; 15, tegmen.
- 16 to 21. *Hindola viridicans* Stål; 16, dorsum of head, pronotum, and scutellum; 17, crown, vertical to its plane; 18, profile view of head and pronotum; 19, face; 20, tegmen; 21, wing.
- 22 to 24. *Hindola luzonensis* sp. nov.; 22, dorsum of head, pronotum, and scutellum; 23, crown, vertical to its plane; 24, tegmen.

PLATE 3

- FIGS. 25 to 28. *Hindola fulva* sp. nov.; 25, dorsum of head, pronotum, and scutellum; 26, crown, vertical to its plane; 27, tegmen; 28, wing.
- 29 to 31. *Hindola nitida* sp. nov.; 29, dorsum of head, pronotum, and scutellum; 30, crown, vertical to its plane; 31, tegmen.
- 32 to 35. *Chaetophyes bicolor* Schmidt; 32, dorsum of head, pronotum, and scutellum; 33, crown, vertical to its plane; 34, tegmen; 35, wing.
- 36 to 39. *Hindoloides indicus* Distant; 36, dorsum of head, pronotum, and scutellum; 37, crown, vertical to its plane; 38, tegmen; 39, wing.

PLATE 4

- FIG. 1. *Quinquatrus dohertyi* Distant, female. (Drawings by W. E. China, from the type specimen in the British Museum.)
2. *Xenaias notandus* Distant. (Drawings by W. E. China, from the type specimen in the British Museum.)

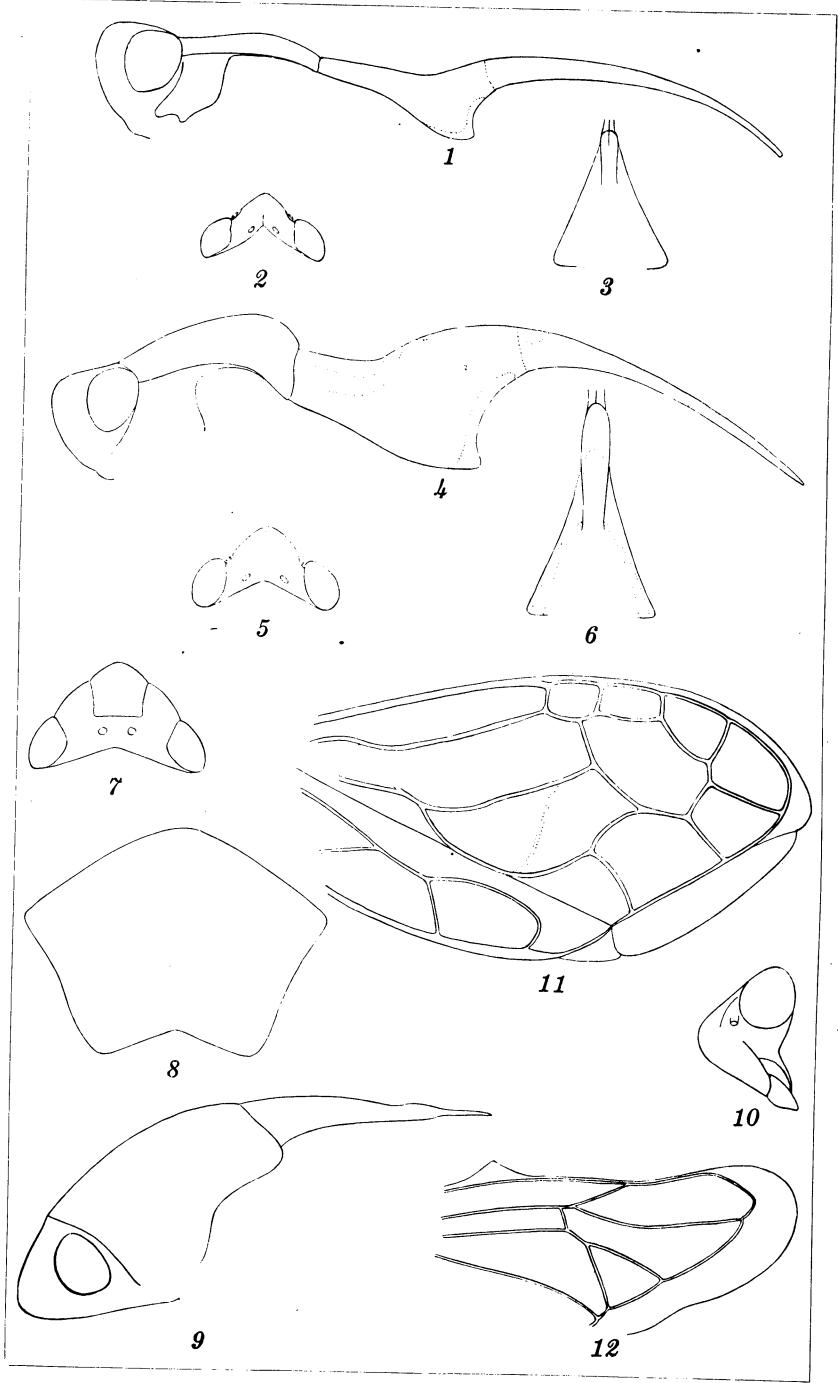


PLATE 1.



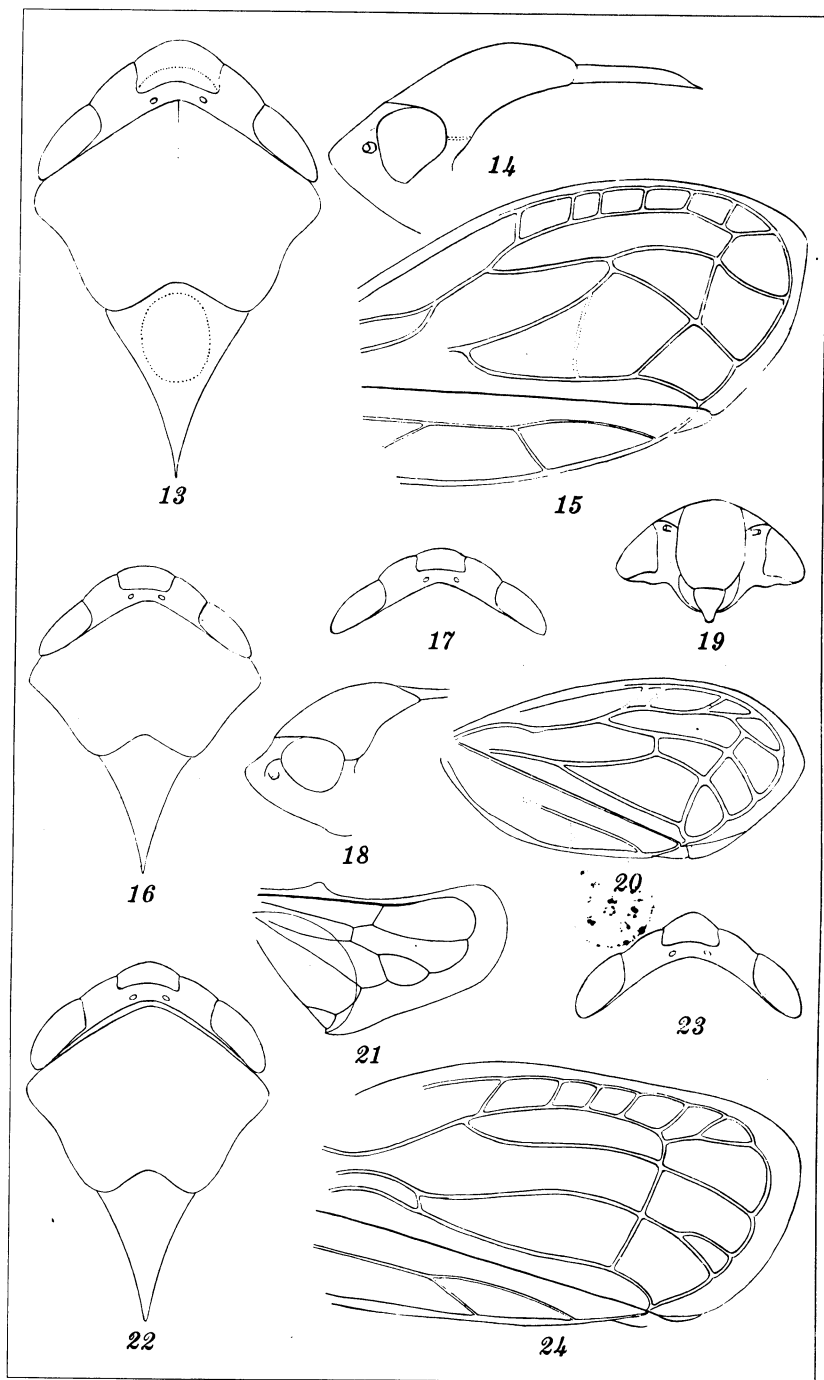


PLATE 2.



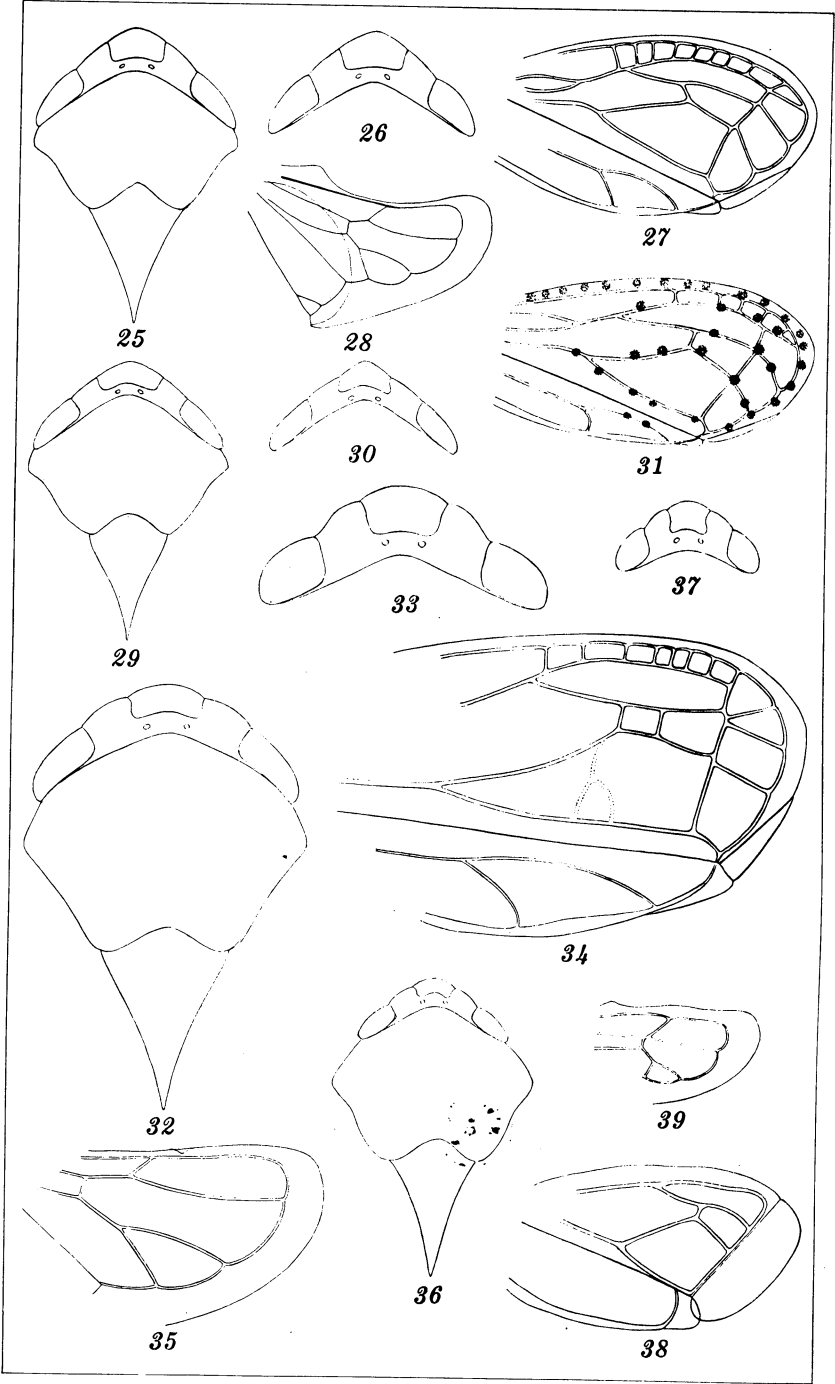
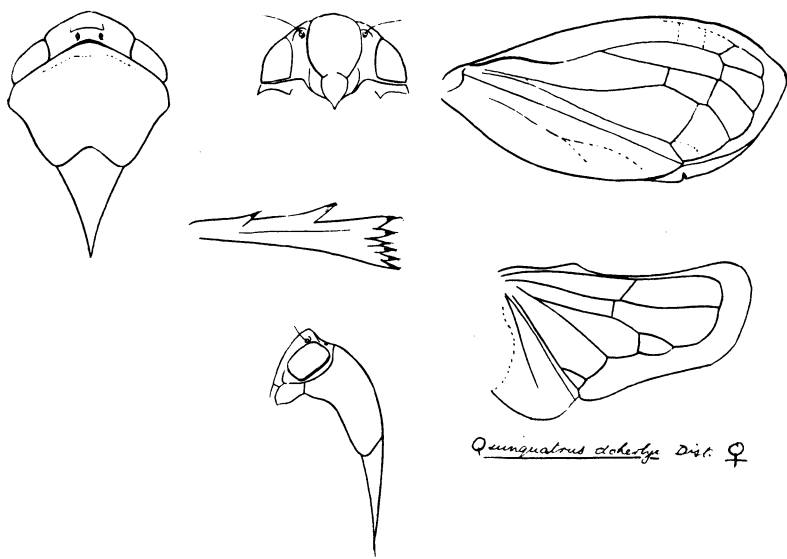
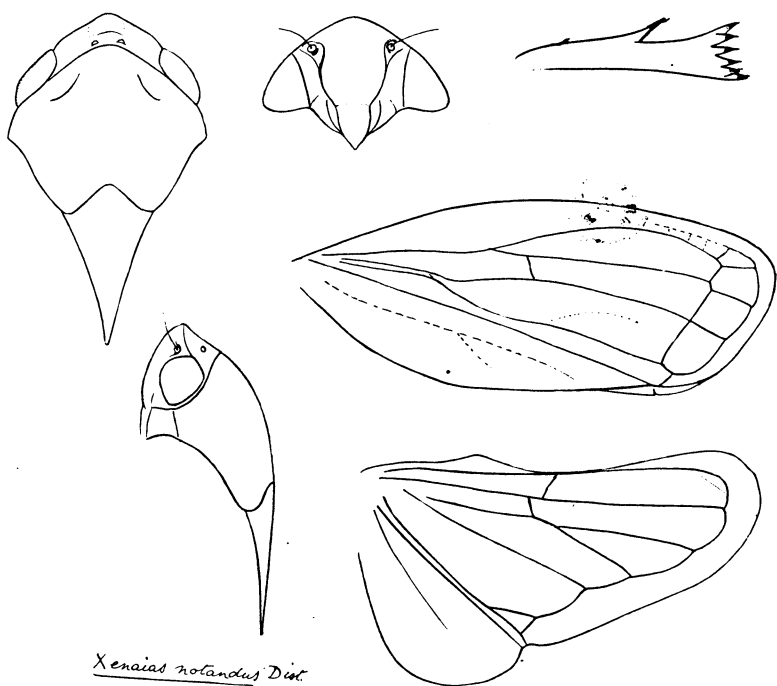


PLATE 3.





1



2



UEBER EINIGE TOMASPIDINÆ (RHYNCHOTA, HOMOPTERA) VON DEN PHILIPPINEN

Von A. JACOBI

Dresden, Saxony, Germany

Mehrere Cercopiden von den Philippinen, um deren Bestimmung mich Herr Baker ersuchte, erwiesen sich als neue Arten, deren Bekanntmachung in dem Philippine Journal of Science er freundlichst vermittelte; die Typen sind im Museum für Tierkunde in Dresden aufbewahrt. Näher eingegangen wird dabei auf die Gattung *Mioscarta* Bredd., die im Archipel der Philippinen einen ziemlichen Artenreichtum entwickelt zu haben scheint. Diese Gattung hat auffallend lange und noch mit langen Anhängseln versehene Subgenitalplatten oder Gonapophysen, aber diese scheinen nicht zu spezifischen Unterschieden ausgebildet zu sein, wenigstens nicht in diesem Faunengebiete, weshalb ich sie in den Artbeschreibungen unerwähnt lasse. Auch die schwarze Zeichnung der Vorderbeine ist bei den dortigen Arten von einer Einförmigkeit, die zu der sonstigen Verschiedenheit der Färbung im Gegensatze steht.

Die Masse sind einschliesslich der angelegten Deckflügel genommen.

MIOSCARTA FERRUGINEA (Walker).

Habitat, Samar (*Baker*); 2 Weiber.

MIOSCARTA SEMPERI Jacobi.

Diese Art, welche Lallemand auf meine Veranlassung hin als Synonym zu der vorigen gestellt hatte, ist doch spezifisch verschieden durch die scharfe Abtrennung des orangegelben Basalteils von dem distalen dunkeln durch eine schwarze Linie und durch die Scheitelzeichnung. Es sind nämlich nur zwei kleine schwarze Pünktchen auf der Quernaht vor den Ocellen vorhanden, während die Gegend zwischen Ocellen und Augen einfarbig ist wie der ganze übrige Scheitel. *Mioscarta ferruginea* hat dagegen immer diesen Zwischenraum der Sehorgane schwarz ausgefüllt und das Rosenrot in der Apikalhälfte der Deckflügel ist weiter ausgedehnt. *Mioscarta rubens* E. Schmidt hat wieder den

Scheitel einfarbig und das Rosenrot in der Apikalhälfte der Deckflügel ist weiter ausgedehnt.

MIOSCARTA BASILANA sp. nov.

Kopf und Brustteil scherbengelb; zwei Pünktchen in den Hinterwinkeln des Stirnscheitelteils, Fühler, Seiten der Stirn in der Basalhälfte und bis zu den Augen und ein sehr feiner, vom Kopf fast verdeckter Vordersaum des Pronotums schwarz. Beine wie sonst gezeichnet. Deckflügel im Basalviertel scherbengelb, im übrigen schwarzbraun, an der Grenze gegen den hellen Basalteil zu schwarz verdunkelt, in der Apikalhälfte aufgehellt und mit einem breiten trübroten Costalsaum, der sich bis zur Apikalspitze ausdehnt; die ganze Fläche der Deckflügel mit dicht anliegendem gelben Filz bedeckt. Hinterleib in der Basalhälfte scherbengelb, apikad schwarz. Im Körperbau sind keine Abweichungen die beständig wären.

Länge, 7 Millimeter.

Habitat, Insel Basilan (*Baker*); 4 Weiber.

MIOSCARTA FLAVOBASALIS sp. nov.

Kopf, Brustabschnitt und Beine ockergelb; Augen braun und scherbengelb marmoriert; neben den Augen eine mehr oder weniger dunkle Trübung. Hinterleib an der Basis und mehr oder weniger in der Mitte der Ober- und Unterseite ockergelb, sonst pechschwarz. Deckflügel im Basalviertel ockergelb, sonst schwarz, der netzadrige Teil aussen mit einem schmalen, rotbraunen Aussensaume. Flügel dunkel rauchgrau, nach der Basis hin noch dunkler, diese selber ockergelb. Im Bau nicht merklich von den übrigen Arten, insbesondere *M. ferruginea*, verschieden.

Länge, 10 bis 11 Millimeter.

Habitat, Insel Samar (*Baker*); 1 Mann und 1 Weib.

POECILOTERPA ATRA sp. nov.

Dunkel pechbraun, im Apikalteil der Deckflügel etwas aufgehellt. Seiten der Stirn, Schnabel und Beine heller braun, gelegentlich ins rötliche ziehend. Strukturell in jeder Beziehung *P. latipennis* E. Schmidt gleich, bis auf das schärfer herausgepresste apikale Geäder der Deckflügel; auch ist diese Art etwas kleiner.

Länge, 4 Millimeter.

Habitat, Insel Polillo (*Böttcher*); 2 Weiber.

Nach dem Aderverlauf in den Flügeln schliesst sich die Gattung *Poeciloterpa* Stål sehr nahe an *Mioscarta* Bredd. an, insofern ihr ebenfalls die Querader zwischen Subcosta und Radius fehlt, aber die Subcosta ist in der Gegend, wo sie sonst von der Quer-

ader getroffen wird, noch viel stärker nach innen ausgeschweift, sodass sie dort zweimal fast im rechten Winkel gebogen ist.

EOSCARTA BOREALIS Distant.

Habitat, Mindanao, Davao (*Micholitz*) ; 1 Weib.

Das einzige Exemplar ist von solchen aus Assam und Laos nicht zu unterscheiden, wobei an die Möglichkeit der Einschleppung in jüngster Zeit gedacht werden darf.

Zwischen *E. laoensis* E. Schmidt und *E. liternoides* Bredd. scheint kein fester Unterschied zu bestehen, da auch die letztere Art in den Diskal- und Apikalzellen dunkle Flecke von verschiedenen starker Tönung zu haben pflegt.

EOSCARTA COLONA sp. nov.

Schmutzig erdbraun, die Vorderfasette der Stirn blass ockergelb, die Stirnseiten schwärzlich; Hinterhälfte des Pronotums, Gegend des Clavus und der Apikalteil der Deckflügel dunkelbraun, das Geäder im Apikalteile wieder hell herausgehoben. Hinterleib auf den Sterniten mit Schwarzen Querbinden. Vorderrand des Kopfes ziemlich stark halbmondförmig gebogen, woraus der Stirn-Scheitelteil wieder etwas hervorragt. Stirn mit groben Seitenfurchen, der Längseindruck bleibt um ein Drittel seiner Länge unter der Basis. Costalrand wenig gebogen, das Apikalgeäder tritt wenig heraus und ist unregelmässig genetzt. Am nächsten wohl mit *E. ferruginea* Distant verwandt.

Länge, 8 bis 9.5 Millimeter.

Habitat, Ostindien, Pondicherry ; 1 Mann und 1 Weib.

COSMOSCARTA LATERALIS sp. nov.

Kopf, Pronotum, Schildchen, Pro- und Mesostethium, Deckflügel schokoladenbraun, bisweilen an der Stirn rötlich aufgehellte; vordere Seitenränder des Pronotums und die Zeichnung der Deckflügel rötlich ockergelb; letztere besteht aus drei Flecken an der Basis, drei mittleren in Corium und Clavus und einer gewinkelten Querbinde vor dem Apikalteile. Ocellen bernstein- bis rötlichgelb. Flügel hell rauchgrau, die Adern an der Basis hellrot. Beine dunkel ziegelrot, beim Mann (1 Exemplar) die Vorder- und Mittelbeine dunkelbraun. Hinterleib gelbrot bis ziegelrot, in schwankender Ausdehnung geschwärzt.

Ocellen unter sich und von den Augen gleichweit entfernt. Pronotum in der Mitte stark gewölbt, vordere und hintere Seitenränder sanft gebogen. Basaldorn der Hinterschienen winzig klein.

Länge, 12.5 bis 15 Millimeter.

Habitat, Insel Samar (*Baker*) ; 1 Mann und 1 Weib.

FOUR NEW CHALCID FLIES FROM THE PHILIPPINES

By A. A. GIRAULT

Of the Department of Agriculture, Brisbane, Queensland

The following chalcid flies were received from and collected by Prof. C. F. Baker. The types are in the Queensland Museum. The generic position of *Macrodontomerus silvifilia* sp. nov. is uncertain, but its description gives all essentials necessary.

EUPELMINIÆ

EUPELMINI

CALOSOTA SPLENDIDA sp. nov.

Ovipositor stylate, compressed, nearly half of rest of abdomen, exceeding any segment; eyes naked; scutellum margined laterad. Antennæ at end of eyes, scrobes deep, joining halfway up and attaining median ocellus, a curved, narrow sulcus from each antenna to end of head. Furrows half complete, faint sutures well separated, nearly straight lines from cephalad and not far from median line. Postmarginal over twice the well-developed stigmal. Large, rather slender.

Brilliant green, scape except apex and legs except coxæ red; apex tegula dark red; abdomen above and a large conic marking from cephalic end of scutum (green along the furrows) to near center of scutellum (blunt at its apex) coppery; forewing lightly infuscated and with a narrow middle line of dark fuscous from apex to under base of bend of submarginal.

Prothorax shining, some hairs on each side cephalad; face and lower cheeks umbilicately punctate, parapsides more coarsely and densely so; rest of mesonotum finely punctate and reticulate, densely pilose; spiracle large, oval; upper occiput densely pilose; mesopleurum naked, reticulated, this sculpture gradually changing to punctuation cephalad. Funicle 1 twice longer than wide, equal to 8, a bit shorter than pedicel; 2 elongate, thrice 1; the rest gradually shortening, club equal 5.

A female, Cuernos Mountains, Occidental Negros, Negros. Not typical for the genus.

TRYDYMINÆ

METASTENINI

METASTENOIDES FERUS sp. nov.

Clypeus strongly bidentate at meson; less robust than in the genotype, propodeum noncarinate, with an obscure cross ridge before middle; segment 7 longest, then 2 and 6, the three united half of surface; 3 to 5 equal, each not two-thirds of 2.—

Aëneous, wings clear, coxæ, femora concolorous, tibiæ 1 and 2 save apex, 3 at proximal one-half, dark brown, rest of tibiæ, tarsus 3 and 1 of tarsi 1 and 2, white. Scape, pedicel red brown, rest of antennæ black, a bit suffused reddish. Lateral ocelli closer to median than to eye.

Scape twice the club; funicle 1 two and a half times longer than wide, 2 and 3 twice longer than wide, 5 one-third longer than wide, equal pedicel.

Tegulæ yellow; postmarginal nearly twice the elongate stigmal. Ciliation to about middle bend of submarginal, then after a short space more loosely to base on more than cephalic half.

A female, Cuernos Mountains, Occidental Negros, Negros.

CLEONYMINÆ

Genus **THAUMASURELLOIDES** novum

Differs from typical *Thaumasura* in having 13-jointed antennæ, club 3-jointed, ring joint large; abdomen rounded above and with only four segments between propodeum and stylate part, the first (or 2) very short, the fourth (or 5) longest and with a median carina; 6 and 7 stylate, 6 longest segment and 7 next, ovipositor extruded beyond them for over the length of 6 and 7; stylus and ovipositor over twice the rest of body, straight. Fore and hind femora slender, unarmed, large.

Type, *Thaumasurelloides silvae* sp. nov.

THAUMASURELLOIDES SILVAE sp. nov.

Dark blue, wings subhyaline, base of scape, tibiæ except 3 at basal one-half more or less, femora except 1 and 3 more or less, tarsi, tegulæ dark red. Densely punctate including propodeum and abdomen, finest on pronotum and vertex, almost reticulation on occiput, coarser on thorax than on abdomen, nearly reticulation on stylate segments which are carinate at meson above. Ciliation to base of wing except caudad. Funicle 1 somewhat longer than wide, 2 longest, two and one-half times longer than wide, 3 twice longer than wide, 8 quadrate. Club 1 half that region. Hind tibial spurs short, subequal.

Propodeum with short, strong median carina, spiracle large, curved, no sulcus. Segment 5 of abdomen longer than wide. Lateral ocellus a bit closer to median than to eye but farther apart from each other than to eye. Eyes hairy, upper thorax pilose. Pedicel not elongate, distinctly shorter than funicle 2; club short but longer than distal funicle.

A female, Mount Maquiling, Luzon (*Baker*), type.

Cotype, a half smaller female, Cuernos Mountains, Occidental Negros, Negros.

This remarkable form belongs to a group difficult to classify, since it has been divided upon a variable amount of swelling in the femora, and recent studies lead me to believe that some duplication of genera has taken place.

TORYMINÆ

MONODONTOMERINI

MACRODONTOMERUS SILVIFILIA sp. nov.

Antennæ 13-jointed, one ring joint; hind femur beneath armed with a distinct, rather large, acute pale tooth; scutellum with distinct cross suture. Hind femur excised distad of tooth. Maxillary 4-labial, palpi 3-jointed. Abdomen compressed, the ovipositor slightly exceeding it. Propodeum noncarinate, at base with four large foveæ, the two at meson very large; a large slitlike spiracle from which a wide sulcus runs. Postmarginal over twice the short, curved stigmal.

Brilliant green, wings clear. Knees, tibiæ, tarsi, scape white; a little over distal half of the clavate tibiæ 3 black. Pedicel brownish.

Scutellum umbilicately punctate, glabrous beyond cross suture, rimmed at apex. Scutum and parapsides with numerous smaller punctures and cross striation, punctures denser and larger on lateral parapside. Axillæ subglabrous at base. Head pilose and with pin punctures, rougher on vertex and with cross rugæ. Upper occiput margined. Lateral ocellus slightly closer to median than to eye. Upper thorax and vertex pilose.

Funicle 1 a half longer than wide, 7 slightly longer than wide, much exceeding the cup-shaped pedicel. Ring joint cup-shaped. Jaws 3-dentate, 1 and 2 acute, 3 wide.

Two females, Cuernos Mountains, Occidental Negros, Negros (*Baker*).

INTRAHEPATIC ADMINISTRATION OF DRUGS

By F. A. FIDELINO and P. A. PAÑGAN

*Of the Department of Pharmacology, College of Medicine
University of the Philippines, Manila*

SIX PLATES

INTRODUCTION

In 1923 Waddell¹ called attention to the intrahepatic route as a convenient method of administering drugs to small animals such as turtles, rats, and frogs. He claimed that the dosage and the time of absorption were more uniform under this method than with application direct to the organs (dropping the solution on them) or with subcutaneous or gastrointestinal administration. The quick onset of effect was attributed by him to rapid absorption.

We also have obtained quick action from intrahepatic administration, but this was not always due to absorption and the effects of the drugs were not uniform. The response of a frog's heart to stimulant drugs was capricious. Moreover, we have obtained effect from plain Ringer solution that was sometimes indistinguishable from that from caffeine or epinephrine. The main feature of our work, which is based on more than one hundred fifty experiments, is reported in this paper.

Method.—The plan of the experiment was simple. It consisted simply of injecting drug and control solutions into the liver substance and recording the cardiac contractions. Frogs (*Rana vittigera*) were used in the experiments. The animal was pithed; the liver and the heart were exposed by a median ventral incision. The pericardium was opened and the apex of the heart was connected in the usual manner with a light lever. The cardiac contractions were recorded on a slowly revolving drum. A tuberculin syringe was filled with the solution and was so arranged that the point of the needle was deep in the liver substance and injection could be made without disturbing the record of the kymograph. Both of us were able to make such

¹ Journ. Pharmacol. & Exp. Therap. 21 (1923) 225.

injections after a little practice. In order to avoid distention of the auricles the volume of the solution should be small and it should be injected slowly.

Mechanism of absorption.—The quick onset of systemic effect from intrahepatic injection has been attributed to rapid absorption. We have frequently observed that injections producing such effect also caused slight but definite distention of the auricles. With dead frogs of medium size 3 minims of a solution slowly injected also caused auricular distention. It is apparent that increasing degrees of distention would result if a series of injections were made of a preparation the circulation of which tends to weaken to a standstill, the maximum distention occurring at the complete cessation of the arterial circulation. In other words, by intrahepatic administration, at least part of the solution is apparently injected directly into the heart. As a matter of fact, air bubbles and colored solutions could be easily injected into the heart by the intrahepatic route. Colored solutions can be readily seen in the heart after its blood has been replaced by Ringer solution. That absorption from intrahepatic injection occurs there is no question, but we believe that the quick onset of effect is largely due to the portion of the solution that is injected directly into the heart.

Response of the heart.—Drugs intrahepatically administered produced variable results. This was especially true with heart stimulants such as caffeine and epinephrine. When the heart was still strong these drugs frequently produced a weaker contraction and an increased tone which could not be attributed to a toxic dose, for the same dose sometimes caused stimulation in the same frog. Stimulation usually occurred if the drug was administered when the heart had been weakened through prolonged contraction. The dose producing stimulation was usually ineffective on second administration. Ether and chloroform regularly brought about their characteristic depressant action. The method is indeed simple for demonstrating the action of these drugs upon the heart. However, it cannot be used to show the characteristic effect of caffeine and epinephrine, for Ringer or saline solution produced stimulation similar to that caused by those drugs. The stimulation in the one instance is sometimes indistinguishable from that in the other. With strophanthin the effect is gradually increasing tone to a standstill. This is similar to the effect of strophanthin as

described by Straub² in connection with his well-known preparation. The intrahepatic route demonstrates beautifully the antagonism of pilocarpine and atropine.

Intrahepatic administration vs. perfusion in situ.—The frog's heart responded regularly to the drugs that were used in these experiments when the heart was perfused with Ringer solution through the vena cava, as in Mines's method,³ using a cannula with a "chimney" for introducing drugs to the heart. The insertion of the cannula in the vena cava in this method is more difficult than is the introduction of the needle in the intrahepatic; but, in testing the effects of drugs on the heart, the former method gives more satisfying results.

SUMMARY

1. Intrahepatic administration is at least partly intravenous or intracardiac injection.
2. The effects of caffeine and epinephrine on the frog's heart are variable when these drugs are administered by the intrahepatic route. They may cause depression or stimulation, depending upon the condition of the heart at the time of the injection.
3. Ringer and plain physiological salt solution injected intrahepatically produce cardiac stimulation which is sometimes indistinguishable from that caused by caffeine or epinephrine.
4. The intrahepatic administration is convenient for demonstrating the effects on the heart of cardiac depressants, the antagonism of atropine and pilocarpine, and the increased tone produced by digitalis.
5. Frog's heart responds more regularly to drugs administered by way of the vena cava, as in Mines's method, than by intrahepatic administration.

² Biochem. Zeitschr. 28 (1910) 392.

³ Journ. Physiol. 46 (1913) 188.

ILLUSTRATIONS

[In all cases the tracings read from left to right: the upstrokes show systoles. The time, when indicated, is marked in seconds.]

PLATE 1. INTRAHEPATIC ADMINISTRATION

- FIGS. 1 and 2. Caffeine and epinephrine depression.
3 and 4. Caffeine and epinephrine stimulation.

PLATE 2. INTRAHEPATIC ADMINISTRATION

- FIG. 1. Epinephrine at the beginning of the experiment.
2. Epinephrine on the same heart later.
3. First dose of epinephrine stimulant; second dose of the same size ineffective.

PLATE 3. INTRAHEPATIC ADMINISTRATION

- FIG. 1. Ether.
2. Chloroform.

PLATE 4. INTRAHEPATIC ADMINISTRATION

- FIGS. 1 and 2. Ringer solution.
3. Caffeine.

PLATE 5

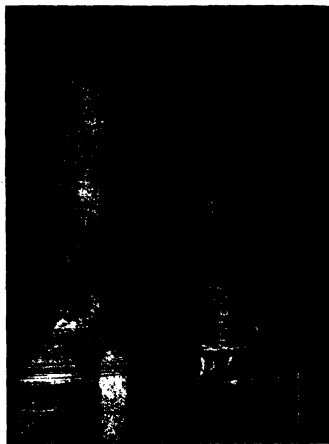
- FIG. 1. Intrahepatic strophanthin.
2. Pilocarpine-atropine antagonism by intrahepatic injection.

PLATE 6. PERFUSION OF HEART IN SITU THROUGH THE VENA CAVA WITH DRUGS ADMINISTERED BY WAY OF THE "CHIMNEY" OF THE CANNULA

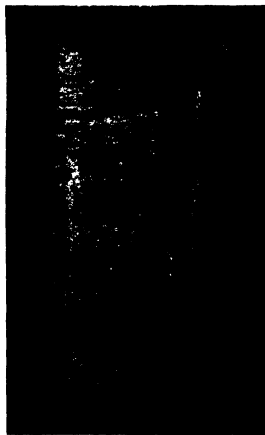
- FIG. 1. Chloroform.
2. Caffeine.
3. Epinephrine.



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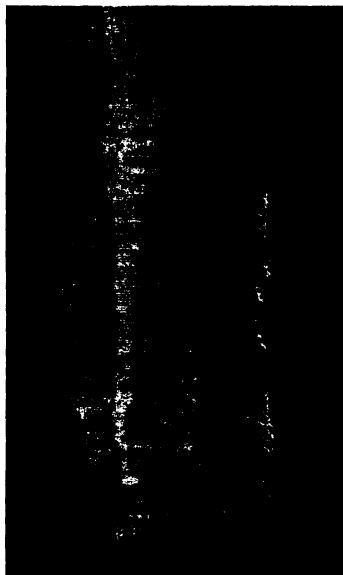
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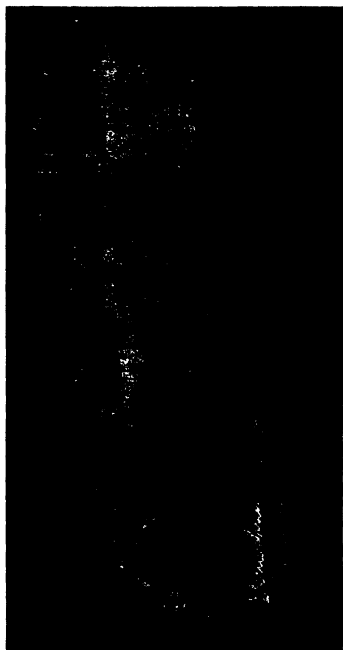
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PLATE 1.

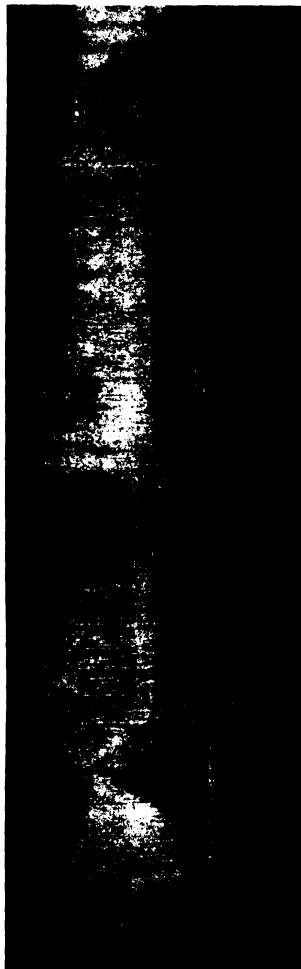




1



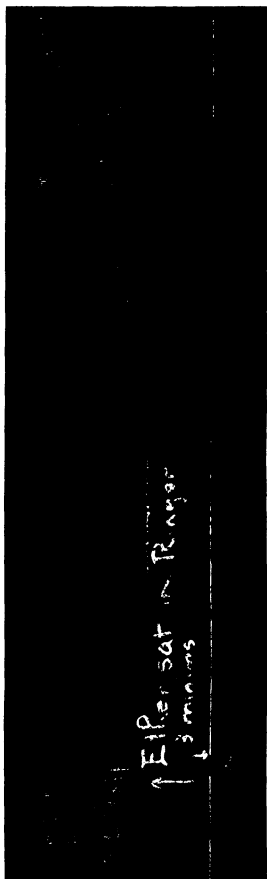
2



3

PLATE 2.





1



2



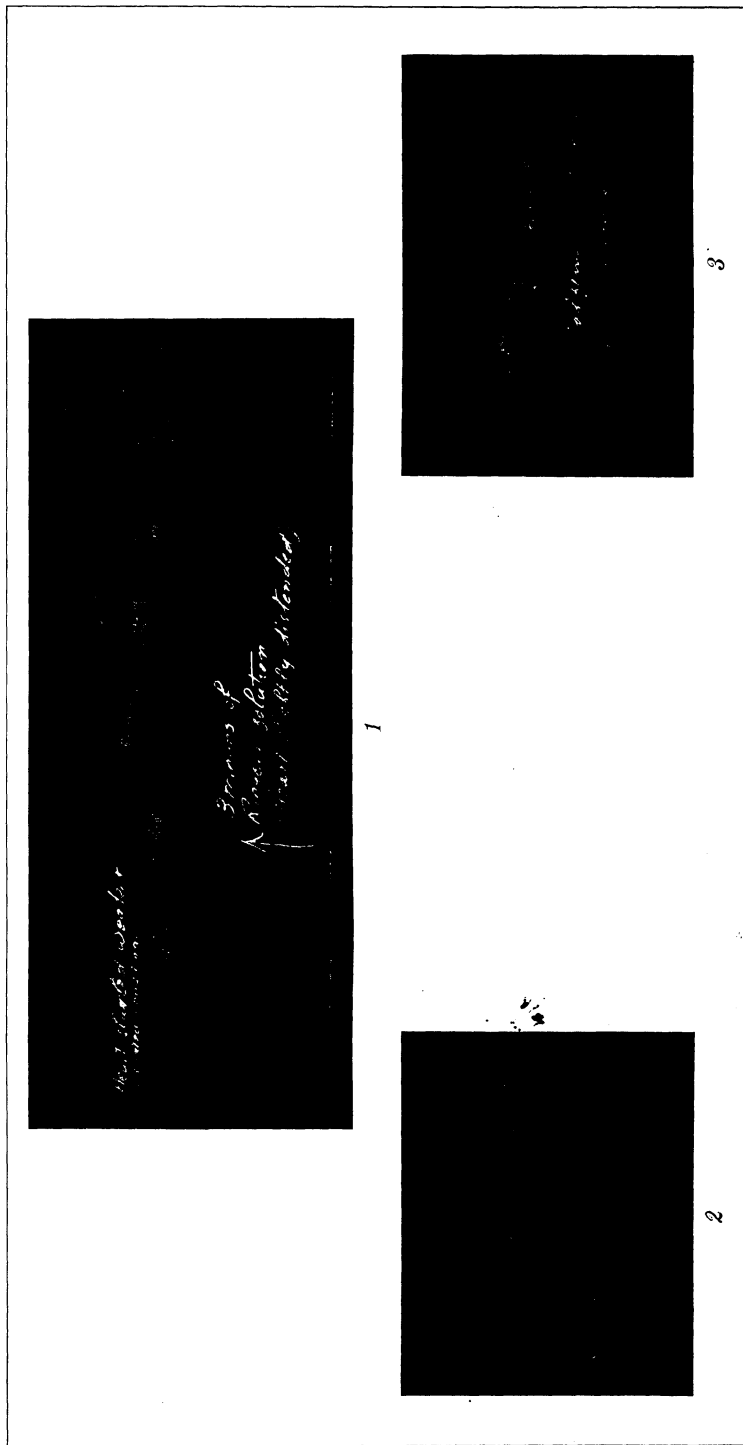
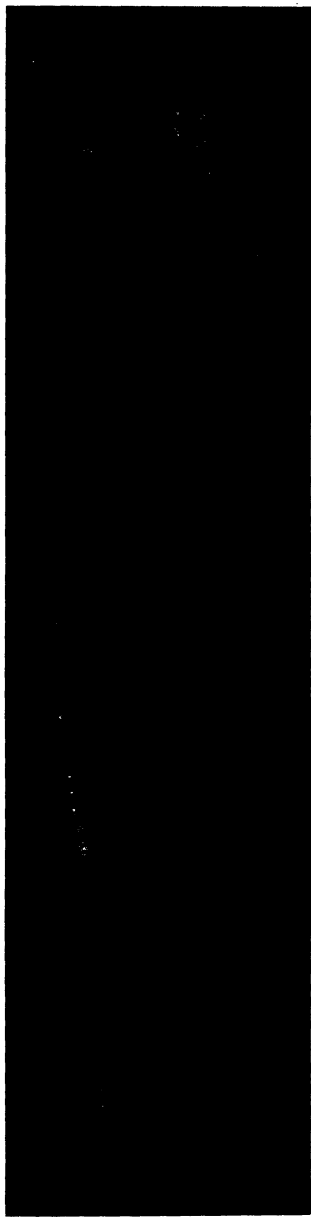


PLATE 4.



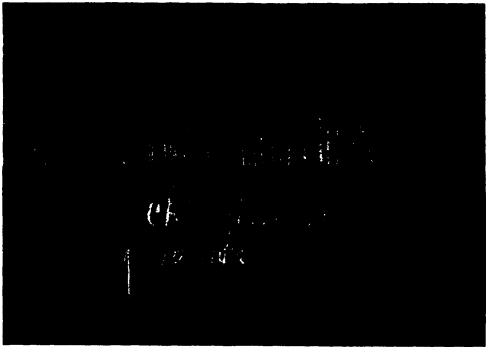


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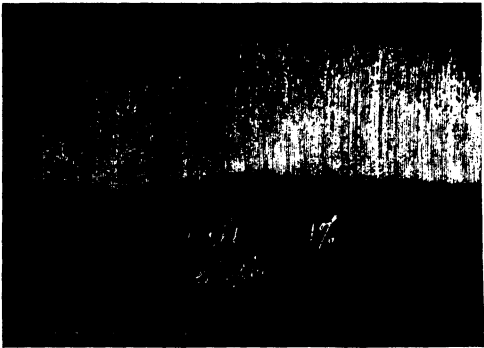


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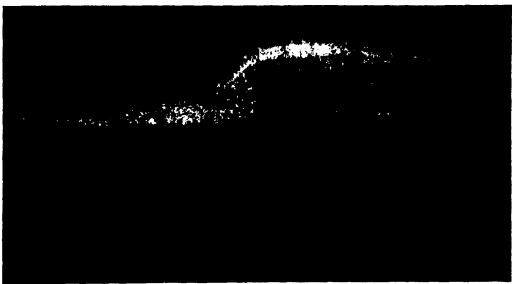




1



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[New generic and specific names and new combinations are printed in **clarendon**; synonyms and names of species incidentally mentioned in the text are printed in *italic*.]

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